VAN NOSTRAND'S
ECLECTIC
ENGINEERING MAGAZINE.

No. XLVIII.—DECEMBER, 1872.—Vol. VII.

# THE SOURCE OF SOLAR ENERGY.

By CAPTAIN JOHN ERICSSON.

From "Nature."

All incandescent bodies shrink rapidly if permitted to radiate freely, the rate being nearly proportional to the degree of incandescence. The enormous temperature maintained at the surface of the sun must therefore produce rapid shrinking, although we do not know the rate by actual observation. We know, however, what amount of mechanical energy the sun parts with in a given time, and we know the size and the specific gravity of the solar mass.

Demonstration is not needed to prove that motion of the particles within a spherical body towards the centre, caused by attraction, develops a certain amount of mechanical energy resulting in the generation of heat within the mass. Nor is it necessary to show that the fixed relations between heat and energy enables us to determine the extent of contraction produced by gravitation, during cooling, if we can ascertain the amount of heat radiated in a given time, by a sphere of known size and specific gravity. With reference to the sun, the elements thus specified are of the following magnitudes: Heat radiated per minute, 312,000 thermal units from one square foot of surface; diameter, 852,584 miles; specific gravity, 0.250 compared to that of the earth, or $5.50 \times 0.250 = 1.37$ of water. Hence, assuming that the mass is homogeneous, the weight of one cubic foot of the matter composing the sun will be $62.5 \times 1.37 = 85.6$ lbs. It will be seen, presently, that in case the sun's mass is not homogeneous, the want of homogeneity will not materially affect the question of attraction and the resulting energy. At first sight, it would appear that no probable amount of contraction of the sun could develop by gravitation towards the centre, an amount of dynamic energy of $312{,}000 \times 772 = 240{,}864{,}000$ foot-pounds per *minute*, for each square foot of the solar surface. Yet, so vast is the mass contained in a spherical pyramid, the base of which is one square foot, and whose length is equal to the sun's radius, that a very small longitudinal contraction suffices to develop by gravitation towards the sun's centre, the stated enormous dynamic energy. It will be readily understood that the energy developed by the shrinking of a spherical pyramid, the sides of which are sectors of the great circle of the sun, will represent accurately the energy produced by the shrinking of the entire mass. And, in view of the great dimensions of the sun and the formidable array of figures involved in the computation of the energy exerted within the entire sphere, the advantage of considering only the mass covered by a single square foot of the solar surface will be evident.

Let I K S, Fig. 1, represent the great circle of the sun, $a\ m\ a'$ the spherical pyramid referred to, and Fig. 2, the said pyramid drawn to a larger scale, its axis being

divided into ten equal parts. It is proposed to ascertain what extent of longitudinal contraction of the spherical pyramid $a\,m\,a'$ is necessary to produce an amount of dynamic energy corresponding with that developed by the radiation from 1 sq. ft. of the solar surface in a given time. The investigation will be somewhat facilitated if we compute the amount of energy developed by a definite contraction of the sun's radius, say one foot. Let us, therefore, suppose that $a\,a'$, the distance of which is $\frac{852{,}584}{2} \times 5{,}280 = 2{,}250{,}821{,}760$ ft. from $m$, has fallen through a space of one foot, the intermediate points $b$, $c$, $d$, etc., participating proportionably in the fall. Assuming that the solar mass remains homogeneous during the contraction, it follows from Newton's demonstration ("Principia" Lib. i., Prop. LXXIII) that, since a particle just within the circumference of the sphere at $a$, is ten times further from the centre $m$ than a particle at $l$, the former will be attracted towards $m$ with ten times greater force than the latter. It will be readily perceived that, for a given movement towards the centre, the quantity of matter put in motion at $a$, will be greater than at $l$, in the ratio of the squares of $a$, $a'$ and $l$, 1 or

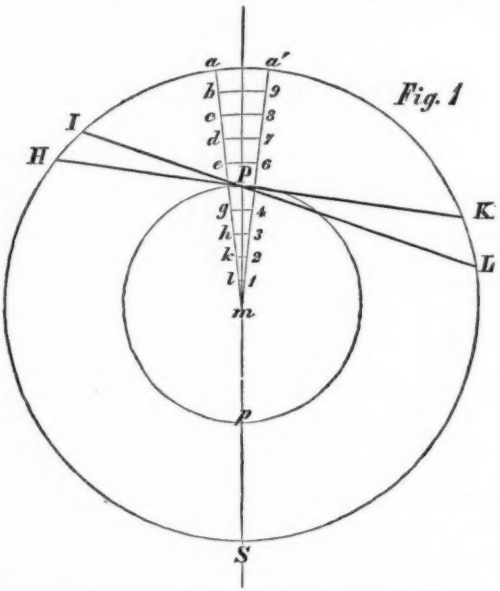



*Fig. 1*

100 : 1. Hence in accordance with the demonstration referred to, a given radial depth of the solar mass at $a$, will exert a force towards $m$, $10 \times 100 = 1{,}000$ times greater than an equal radial depth at $l$. But in computing the dynamic energy developed by the shrinking of the sun, it must be borne in mind that a particle at $a$ falls through a distance ten times greater than a particle at $l$. The length of the ordinates of the curve $p\,t$, Fig. 3, representing the ratio of dynamic energy developed at the respective distances from the sun's centre, has been calculated accordingly. A cursory examination of Fig 2, can scarcely fail to lead to the conclusion, that the mass composing the smaller sections of the spherical pyramid towards the centre of the sphere, will be attracted by the larger mass composing the sections towards the circumference. Newton has disposed of this question by a geometrical demonstration, which, considering the form of the attracting mass, and the extreme complication arising from the varying direction and unequal magnitude of the attracting forces, may be regarded as one of the most elegant of his masterly demonstrations of important propositions and theorems. It will be evident on reflection that, unless it can be proved that a

particle at P, is not attracted by any portion of the mass contained within the outer spherical superficies I K S and the interior spherical superficies P *p*, the mass composing the sections near the base of the spherical pyramid will exert the disturbing attraction before alluded to. Our demonstration of the energy produced by the attraction of the matter within the sun, during shrinking, falls to the ground unless it can be shown that every particle composing the spherical pyramid, is in perfect repose as regards the attraction exerted by exterior particles. The great geometer thus establishes that

*Fig. 2*

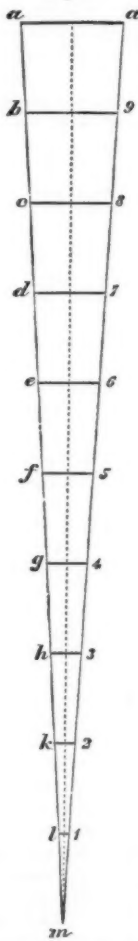
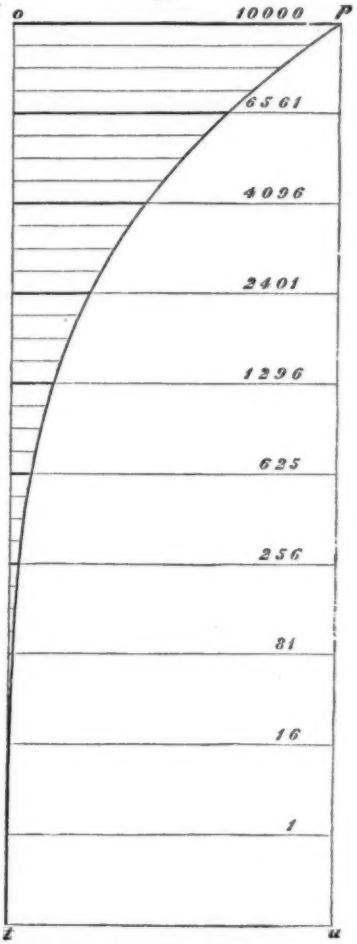



*Fig. 3*




repose :—Let H I K L be a spherical superficies and P a corpuscle placed within.* Through P let there be drawn to this superficies the two lines H K, I L, intersecting

* Sir Isaac Newton in his demonstrations relating to spherical bodies supposed these to be composed of an infinite number of spherical superficies, the thickness of which he thus defines: "By the superficies of which I here imagine the solids composed, I do not mean superficies purely mathematical, but orbs so extremely thin, that their thickness is as nothing; that is, the evanescent orbs of which the sphere will at last consist, when the number of the orbs is increased, and their thickness diminished without end."

very small arcs H I, K L; and because the triangles H P I, L P K, are homogeneous, those arcs will be proportional to the distances H P, L P, and any particles at H I and K L of the spherical superficies, terminated by right lines passing through P, will be in duplicate ratio of those distances. Therefore the forces of these particles exerted upon the body P, are equal between themselves. For the forces are as the particles directly, and the squares of the distances inversely. And these two ratios compose the ratio of equality. The attractions, therefore, being made equally towards contrary parts, destroy each other. And, by a like reasoning, all the attractions through the whole spherical superficies are destroyed by contrary attractions. Therefore the body P will not be anyway impelled by those attractions.

Referring to Fig. 3, let us recollect that the ordinates of the curve *p t*, do not indicate the force exerted by mere attraction. As already stated, their length represents the dynamic energy developed at definite distances between the centre and the circumference of the sphere. The energy actually produced is represented by the superficies *o p t*, while the rectangle *o p u t* represents the energy that would be called forth if the force exerted at every point of the axis of the spherical pyramid were the same as that exerted at *a a'*. Our space will not admit of introducing the calculations by which the energy represented by the ordinates of the curve *p t*, have been computed. It will be proper, however, to call attention to the fact that the energy exerted at each of the divisions of the base line *o t*, is definite; hence the length of the ordinates is exact. Calculations based on the data thus furnished show that the superficies *o p t* is 0.20015 of the superficies *o p u t*.

We have before stated that the want of homogeneity of the solar mass will not materially affect the amount of energy developed by the gravitating force during the sun's shrinking. Referring to the several figures, it will be seen that the energy exerted at a point half way from *m*, viz.: ordinate 5, is 0.0625 or $\frac{1}{16}$ of that exerted at *a a'*; and that the energy developed by the mass contained within the spherical pyramid *f m* 5 amounts to only $\frac{1}{31}$ of that developed by the gravitation of the mass contained within the spherical pyramid *a m a'*. Now, the volume of the spherical pyramid *f m* 5 represents that of a sphere the diameter of which is one-half of the sun, while the spherical pyramid *a m a'* represents the volume of the entire solar mass. The energy resulting from the gravitation of the central spherical mass P *p* being thus only $\frac{1}{31}$ of the energy exerted by the spherical mass I K S, it will be perceived that the degree of density of the matter towards the sun's centre will not materially affect the result of our calculations founded on perfect homogeneity.

We may now proceed to ascertain the amount of dynamic energy produced by the assumed shrinking of the axis of the spherical pyramid *a m a'*. Having already demonstrated that the said energy will be 0.20015 of that produced by the gravitation of a homogeneous mass, the section of which is one square foot, extending from the surface to the centre, it only remains to determine the weight of one cubic foot at the surface of the sun. The specific gravity of the solar mass being 85.6 lbs. per cubic foot, while the sun's attraction is 27.2 times greater than terrestrial attraction, the weight of one cubic foot at the solar surface will be $27.2 \times 85.6 = 2328.3$ lbs.; multiplying this weight by the sun's radius, expressed in feet, we have

$$2328.3 \times 2{,}250{,}821{,}000 = 5{,}240{,}633{,}000{,}000,$$

which product multiplied by 0.20015 shows that the gravitating energy of the matter contained in the spherical pyramid, exerted during a longitudinal contraction of one foot, amounts to 1,048,912,000,000 foot-pounds. Dividing this latter product by the solar energy per minute ($312{,}000 \times 772$), we find that 4,355 minutes = 3.024 days, will elapse before the energy produced by constant solar radiation equals the gravitating energy exerted during the shrinking of 1 ft., of the solar radius. The length of one year, 365.25 days, being divided by 3.024, we learn that the annual shrinking of the sun's radius amounts to 120.7 ft. The foregoing figures prove that, notwithstanding this apparently great contraction, a period of 1,864 years is necessary to diminish the sun's diameter $\frac{1}{10000}$. It hardly requires explanation that this result is reached by dividing the sun's radius by 10,000 times the stated annual shrinking.

Helmholtz, in accordance with Laplace's remarkable nebular hypothesis, asserts that the continuation of the original condensation of the matter composing the sun, de-

velops an amount of mechanical energy capable of generating sufficient heat to make good the present solar emission. According to his calculations, the sun's diameter will be reduced $\frac{1}{1000}$ in the course of 2,000 years. The practical data assumed by the eminent physicist being less accurate than those upon which our calculations are based, the discrepancy regarding time, 2,000 years against 1,864 years necessary to effect the stated shrinking of the sun's diameter, may be satisfactorily explained. It will be well to observe that the intensity of the radiant heat will not diminish with the diminished size of the sun. On the contrary, for a given area of the solar surface, the dynamic energy produced by a given rate of shrinking will be increased, since the mass remains the same, while the attraction is inversely proportional to the square of the distance from the centre. But the *rate* will diminish with the contraction of the sphere; hence a shrinking of $\frac{1}{10}$th of the sun's diameter instead of occupying $1000 \times 1864 = 1{,}864{,}000$ years, will require somewhat more than 2,000,000 years. At the end of that period, the gravitating energy will continue to develop as at present, an amount of dynamic energy represented by 312,000 thermal units per minute for each superficial foot; but the radiating surface, *i. e.* the area of the solar disk, will have diminished in the ratio of $10^2$ to $9^2$.

The present maximum temperature produced by solar radiation on the ecliptic when the earth is in aphelion, being 67.2 deg., while the intensity of radiant heat diminishes as the area of the radiating surface, it follows that at the end of 2,000,000 years from the present time, the tropical solar intensity will be reduced to $\frac{9^2 \times 67.2}{10^2} =$ 54.4 deg. — unless Prof. Tyndall's opinion is correct, that the earth in common with the other planets must "creep in, age by age, towards the sun."* But the pace is no doubt so slow that our calculations will not be seriously affected; hence applying the foregoing demonstrations to the past, it will be seen that the temperature produced by solar radiation 2,000,000 years ago must have been, owing to the greater diameter of the sun at that period, nearly $\frac{11^2 \times 67.2}{10^2} =$ 81 deg. within the tropics. We are justified in assuming that the increased evaporation of the sea and the consequent humidity of the atmosphere, modified the stated solar intensity, calling forth the luxuriant flora which geology has made us acquainted with. The computed diminution of solar intensity 67 deg. — 54 deg. = 13 deg. during the next 2,000,000 years, will probably be deemed extravagant by those who do not bear in mind that the computation must be based on the assumption that a constant power will be exerted during the stated period, capable of developing as at present, the stupendous energy of 240 millions of foot-pounds in a single minute, for each square foot of the surface of a sphere whose diameter exceeds 850,000 miles. This inconceivable amount of work cannot be performed with a less expenditure than the motive energy developed by the fall of a mass equal to the mass contained in the sun, the weight of which is nearly a thousand times greater than the weight of all the planets of the system. Obviously, a *continuous* development of such an amount of energy is physically impossible, since there is a *limit* to the distance through which the weight can fall. Now, the foregoing demonstration enables us to determine the said limit, with sufficient exactness to prove that although the efficiency of the great motor during the past, may be measured by hundreds of millions of years, its future efficiency will be of comparatively brief duration.

Statements relating to the permanency of solar heat, based on the assumption that no diminution has been observed during historic times, have no weight in view of our demonstration showing that a shrinking of $\frac{1}{10}$ of the sun's diameter can only reduce the intensity from 81 deg. to 67.2 deg., difference = 13.8 deg. in the course of two millions of years. This period being 500 times longer than "historic times," say 4,000 years, it will be seen that the diminution of the temperature produced by solar radiation has not exceeded $\frac{13.8}{500} =$ 0.027, or $\frac{1}{37}$ deg. Fahr., since the erection of the Pyramids.

It will be proper to observe before concluding our brief investigation of the source of solar energy, that the development of heat by the shrinking of the sun, however fully demonstrated, leaves the important question unanswered: How is the heat generated by gravitation within the mass, transmitted to the surface? If the matter

* See "Heat as a Mode of Motion," page 499.

within the sun is a perfect conductor of heat—a very improbable supposition—that fact alone furnishes a satisfactory answer. Imperfect conductivity, on the other hand, calls for other means of transmitting the energy from within, to make good the enormous loss caused by the external radiation. Besides, the falling of the crust at the rate of 10 ft. per month, attended by increase of internal pressure and probably ejection of gaseous matter, together with the disturbance occasioned by contraction at the surface, disclose a mechanism of startling complexity. But, the parting with 312,000 thermal units for each square foot of the solar surface, involving an expenditure of kinetic energy of fully 240,000,000 foot-pounds per minute, cannot be made good in that brief space of time, unless the sun shrinks at the rate ascertained by our calculations.

The development of solar energy in accordance with the combustion hypothesis (lately resuscitated by M. E. Vicaire), merits no consideration; while careful investigation has proved the meteoric hypothesis to be untenable. It must be admitted, however, that the mechanical difficulties alluded to, especially those relating to the means of transmitting the heat to the surface of the sun, any temporary local derangement of which must be productive of dark spots, for a time, are of such a nature that the supposed absolute certainty of solar radiation may be questioned. Nor is evidence wanting to show that the solar mechanism is liable to derangement. History informs us that the great luminary has, during several seasons, partially failed to perform its functions.

Herschel states in his "Outlines of Astronomy," that "in the annals of the year A. D. 536, the sun is said to have suffered a great diminution of light, which continued fourteen months. From October, A. D. 626, to the following June, a defalcation of light to the extent of one-half is recorded; and in A. D. 1547, during three days, the sun is said to have been so darkened that stars were seen in the daytime." Again, the glacial periods, the ascertained abrupt termination and recurrence of which puzzles the geologist, point to periodical derangement of the solar mechanism in past ages.

## THE SOURCE OF THE SOLAR HEAT.

By MAXWELL HALL, B. A.

From "Monthly Notices of the Royal Astronomical Society, April, 1872."

Let us suppose that the mass of the Sun is slowly, but continually, contracting; then, in consequence of the enormous mass subjected to this contraction, an enormous amount of heat will be developed, and it will be found that the rate or amount of contraction necessary to produce the amount of heat radiated by the Sun into space, is so remarkably small, that ages must elapse before the effect of this contraction can become visible to us at our comparatively great distance from the Sun.

In order to show that this is the case, let one foot and one second be taken as the units of space and time, and suppose that each unit of volume of the Sun's mass contracts by the same amount in the same time, so that if $z_0$ be the linear contraction of the Sun's radius $r_0$ in one second, and if $z$ be the contraction of any other length $r$, measured from the centre, and for the same duration of time, then

$$\frac{z}{z_0} = \frac{r}{r_0}.$$

The effect of this contraction may thus be compared to a series of intermittent pulsations, acting throughout the whole of the mass, and tending to diminish the volume. Let $g_0$ be the force of gravity at the surface of the Sun, and let $g$ be the force of gravity at any point within the Sun's mass considered homogeneous, whose distance is $r$ from the centre; then

$$\frac{g}{g_0} = \frac{r}{r_0}.$$

Again, let $\rho$ be the mean density of the Sun's mass, so that the weight of any thin concentric shell, whose radius is $r$ and thickness $\delta r$, will be $4\pi g \rho r^2 \delta r$; and, since every unit of mass in this shell falls through $z$ feet towards the centre in a second of time, $4\pi g \rho z r^2 \delta r$ will be the kinetic energy generated and destroyed every second by this shell alone; and therefore

$$\int_0^{r_0} 4\pi g z r^2 \, dr$$

will be the whole kinetic energy destroyed

every second of time, and we proceed to find the corresponding amount of heat evolved. Now

$$\int_0^{r_0} 4\pi g\rho z r^2\,dr = \frac{4\pi g_0\rho z_0}{r_0^2}\int_0^{r_0} r^4\,dr = \frac{4}{5}\pi g_0\rho z_0 r_0^3,$$

and this is the kinetic energy destroyed by the fall of a weight

$$\frac{4}{5}\pi g_0\rho r_0^3$$

through a height of $z_0$ feet, or by the fall of a weight

$$\frac{4\pi g_0\rho z_0 r_0^3}{5\times 1390}$$

through a height of 1390 feet; but the fall of one pound avoirdupois through a height of 1390 feet generates sufficient heat to raise one pound of water through 1° centigrade, or it generates one thermal unit; hence by expressing

$$\frac{4\pi g_0\rho z_0 r_0^3}{5\times 1390}$$

in foot-pounds we shall get the number of thermal units generated every second of time. Now $g_0\rho$ is the weight of a cubic foot of the Sun's mass at the surface, and since

$g_0$ = 27.20 times the force of terrestrial gravity, and

$\rho$ = 1.43 times the density of water, therefore

$g_0\rho = 27.20 \times 1.43$ times the weight of a cubic foot of water at the surface of the earth. But a cubic foot of water weighs 62.5 pounds, so that $g_0\rho = 2431$ pounds.

Therefore

$$\frac{4\pi z_0 r_0^3\times 2431}{5\times 1390},$$

when both $r_0$ and $z_0$ are expressed in feet, will give us the number of thermal units generated every second of time.

Now, it has been found by observation that the heat emitted by the Sun to the Earth is sufficient to melt a sheet of ice whose thickness is 0.01093 in., when exposed perpendicularly to the Solar rays for one minute (Sir John Herschel, "Meteorology"), due allowance having been made for the heat absorbed by the atmosphere; and, therefore, in one second, a sheet of ice whose thickness is 0.0000152 ft. will thus be melted; so that, if $a$ be the mean distance of the Earth from the Sun, expressed in feet, a spherical shell of ice, whose radius is $a$ and thickness 0.0000152 ft. will be the volume of ice in cubic feet melted every second by the whole of the radiant Solar heat. But one pound of ice has a volume equal to $(0.2584)^3$ cubic feet, therefore

$$\frac{4\pi a^2\times 0.0000152}{(0.2584)^3}$$

will be the weight of the ice in pounds thus melted.

Again, in order to melt one pound of ice,

$$\frac{4\pi a^2\times 79.25\times 0.0000152}{(0.2584)^3}$$

79.25 thermal units are required; and thus the whole Solar heat evolved in one second of time is equal to

$$\frac{4\pi a^2\times 79.25\times 0.0000152}{(0.2584)^3}\text{ thermal units.}$$

Now by equating the heat generated to the heat evolved in one second, we get

$$\frac{4\pi z_0 r_0^3\times 2431}{5\times 1390} = \frac{4\pi a^2\times 79\,29\times 0.0000152}{(0.2584)^3},$$

and the contraction $z_0$ is therefore only 0.000004079 ft. in one second, or 129 ft. per annum; and, as we have already said, ages must elapse before the effect of this contraction can become visible to us, whether we compare direct measures of the Solar disk or observed periods of axial rotation.

The contraction, therefore, is so small, that as much allowance can be made for the assumptions introduced above as may be thought necessary, without altering our general conclusion in the slightest degree, namely, that the source of the Solar heat and light is connected with the mechanical theory of heat by means of the contraction of the composing mass.

The application of this theory to other bodies is almost without limit; the Earth has contracted, and has stored up a corresponding amount of heat in the non-conducting rocks and soils; the stars, by their intrinsic brilliancy, indicate the operation of the force of gravity upon contracting matter; the nebulæ afford examples of the commencement of this operation; and periodical variations in light now become perturbations, the effect of disturbing masses in motion, producing endless changes subject to the great principle known as the conservation of energy.

# THE ROLLING OF SHIPS*.

By P. WATTS.

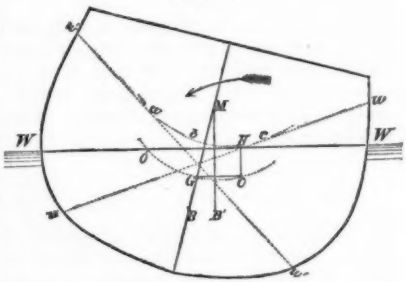
From "The Annual of the Royal School of Naval Architecture and Marine Engineering."

Among the many subjects relative to the designing of ships which have occupied the attention of scientific men of late years, there is none more important or more difficult than the rolling of ships at sea, involving, as it does, elements in their construction which may not be neglected with impunity. Hitherto, so far as practical shipbuilders are concerned, this matter has scarcely, if at all, been considered, except in their endeavor to provide sufficiently for the strains which the structure must undergo when subject to the action of the wind and waves; but there are other considerations in connection with the subject which are almost as important, on which much of the ship's safety depends, and these are generally neglected. Many a well-built vessel that has foundered at sea would probably have had a successful career for years had she been so designed as to comply with theoretical requirements, and thus it should be the earnest endeavor of all concerned to perfect, as far as possible, our present knowledge of the subject, and put in practice what is already known. To this end a succinct account of the results at present obtained may possibly be of service.

In dealing with the subject we shall first take the most simple case—that of a ship rolling in still water—neglecting the resistance of the water, and supposing the vessel to be rolling so that she constantly displaces a quantity of water equal to her weight. Not that these limitations are inconsiderable, but because by allowing them we are enabled to make the following construction, which will materially assist our conception of how the vessel rolls.

Let Fig. 1 represent the ship rolling in the direction indicated by the arrow, W W being the water line in her present position. We suppose her to have been heeled over to some inclination such as that indicated by the position of the water line $w\ w$, and then allowed to oscillate freely under the action of her weight and the upward pressure of the water alone. Let G be her centre of gravity, and B B′ the centres of buoyancy corresponding to the upright and inclined positions respectively, so that M is the metacentre—*i. e.*, the point where B M, the vertical through B′, intersects the original vertical through B and G—the angle of inclination being small. Then, as is well known, M G is a measure of the *righting force*—*i. e.*, of the effort exerted to turn the ship towards the upright position. It is this *righting force* which makes the ship oscillate: as she rolls from the extreme position on one side the *righting force* gradually diminishes, and in the upright position

Fig. 1.




vanishes, but in rolling through this angle it accumulates an amount of work which is just sufficient to carry the vessel to the same inclination on the other side. This is evident from the fact that the *dynamical stability* up to an equal angle of inclination on each side is the same—for the work accumulated by the righting couple, as the vessel passes from the extreme position to the upright, is the dynamical stability corresponding to the angle of heel, and, of course, this is just the work which is required to incline her to the same angle on the other side. The motion of the ship oscillating thus about her upright position is analogous to that of a pendulum, the principal difference being that whereas the bob of a pendulum turns about a fixed point—the point of suspension—the axis about which the vessel rolls *moves* through a certain path dependent on the position of the centre of gravity, and on the figure of the vessel. We proceed to trace this path.

Let us imagine a surface which will constantly touch the plane of the water—supposing it to be continued right through the vessel—as she rolls from side to side; this surface, indicated by $a\ b\ c$, is called the *surface of flotation*.

Now, let us suppose this surface of flotation together with the surface of the water to become rigid surfaces without friction, conceiving the former to be capable of rolling and sliding upon the latter without being interfered with by the material parts of the vessel, except in so far as it will be influenced by the forces of weight and buoyancy acting vertically through the centres of gravity and buoyancy respectively. The motion of the ship under these circumstances, supported by its surface of flotation resting upon the rigid but perfectly smooth water plane, will in all respects be the same (restricted as we have supposed) as if it rolled in the water uninfluenced by these imaginary surfaces. The problem is thus reduced to that of the motion of a solid body, without weight and of fair external surface, upon a smooth horizontal plane acted upon by certain forces.

The instantaneous axis* about which a body is turning is known when the motions of any two fixed points in the body are known. The forces of weight and buoyancy being wholly vertical, the centre of gravity must move in a vertical line; therefore if G be the centre of gravity, the instantaneous axis must be in the horizontal line G O. Also, as the surface of flotation slides upon the plane of the water the instantaneous direction of H, its point of contact, must be along the plane of the water, hence the instantaneous axis must lie in H O, and therefore it is the point O where G O and H O intersect. From this we see (following out the process through the entire motion) that the locus of the instantaneous axis as a ship rolls from side to side will be some such curve as that indicated by the dotted line O GO passing through the centre of gravity and turned up towards its extremities. It may be readily shown from the dynamical equation of a ship rolling under these circumstances, that the time of her roll or oscillation is practically the same as that of a *simple pendulum* whose length is equal to the square of her radius of gyration divided by the height of the metacentre above the centre of gravity.

This kind of imaginary rolling (water set in motion, etc., being neglected) is called *unresisted rolling in still water*. The time of a roll is usually measured by the time it takes for the ship to pass the upright position twice moving in the same direction; it corresponds to what is called a double oscillation in a pendulum.

If we remove the limitations we have made, the case is very materially altered. The keel and sharp parts of the floor and the bilge keels (if the ship has any) tend to set in motion large volumes of water, and the resistance thus caused has a steadying effect on the vessel, diminishing the extent of rolling and lengthening the periodic time. Professor Rankine has shown that by these causes the extent of rolling is diminished nearly in geometrical progression at a rate increasing with the amount of resistance offered, and diminishing as the moment of inertia is increased; and that the time of rolling is increased in the same way as if the radius of gyration were increased in a certain ratio depending directly on the amount of resistance exerted, and inversely on the height of the metacentre above the centre of gravity.

As regards the instantaneous axis, in passing the upright position she will be generally turning about a point a small distance below the centre of gravity, and the locus of the instantaneous axis will probably be considerably turned down and looped towards its extremities, rather than turned up as shown in the figure.

By bearing in mind the locus traced by the instantaneous axis as the ship rolls, we are enabled to form a good idea of the lurching or rolling motion she undergoes.

The consideration of the rolling of ships in still water is of considerable importance, as it depends upon elements in their design which largely determine their rolling properties among waves. In fact, as we shall presently show, when their time of *unresisted rolling in still water* is known, their behavior among waves so far as rolling is concerned may be fairly estimated. We shall now pass on to consider the rolling of ships among waves, and in doing so we shall first examine somewhat the nature and character of waves, in order to more readily understand the action of the hydrodynamic forces they exert.

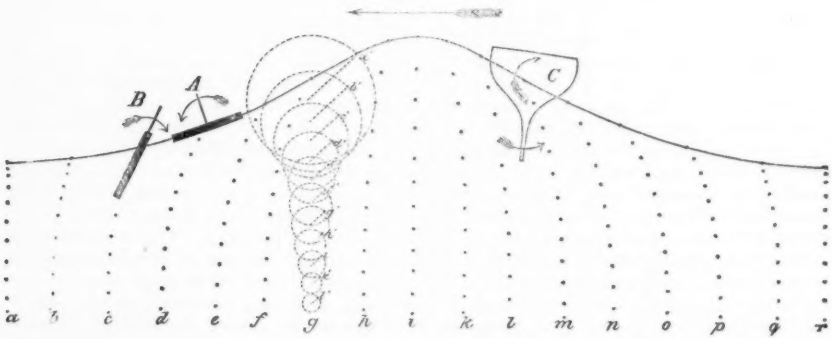
We shall deal with *deep water waves*, the depth being such as not to interfere with the form of the waves, and shall consider the disturbing cause—the wind—to have subsided, and the ocean to be traversed

* This is the axis about which a body may be supposed to turn through a very small angle, considering its motion at any particular instant. The construction of the instantaneous axis given above was pointed out by Canon Moseley.

by uniform waves of the same size running parallel to one another. It is only the *form* of such waves that travels. Theory and observation agree in showing that every particle of water affected by these waves uniformly describes a circle about a point rather above its still water position, as each successive undulation passes it, and we may consider that it is this motion of the water, as a body, which gives the waves their form and speed. The length of a wave is the distance between two successive hollows or crests, measured in the direction in which the wave travels; the height of a wave is the vertical distance between the hollow and crest; and the time or period of oscillation is the time it takes to traverse its whole length.

We will consider the motion of a particle of water on the surface as it is traversed by a wave—commencing from the instant when it is in the middle of the hollow between two crests. Suppose the wave to be passing from right to left. As it moves towards the particle, the latter rises upon its surface, and at the same time moves slowly towards the crest from left to right, this second movement, however, only continuing while the waves run through rather more than half the distance between the hollow and the crest, during which time the particle describes the lower right-hand quadrant of the circle. It then begins to move backwards from right to left with the crest, at the same time being raised by the surface of the wave, describing the upper right-hand quadrant of the circle, which it will have completed when the top of the crest overtakes it. It will then be immediately over the point from which it started. As the wave passes on, it continues moving with it in direction, and at the same time descends on the back slope of the wave, describing the upper left-hand quadrant of the circle; it then moves slowly backwards from the crest, continuing down the back slope of the wave through the lower left-hand quadrant, arriving finally at the instant the wave passes it at the same point from which it started, having described a circle of the same diameter as the height of the wave.* The whole of the surface particles will, of course, be affected in exactly the same way. With regard to the motion of the water below the surface during the passage of a wave, every particle describes a circle in a manner similar to that of the surface particles, but with this difference—the radii are smaller, and decrease in a certain ratio which depends on the depth from the surface.

FIG. 2.




Let Fig. 2 represent a wave such as we are describing. The circles *a*, *b*, *c*, etc., are paths described by a number of particles which, if the water were at rest, would be in a vertical line and equidistant from each other. The motion undergone by this line of particles may be readily followed by keeping in mind how each particle traverses its orbit as the wave passes. The dots in the lines *a b c d*, etc., indicate the positions occupied by these particles as they are passed by the corresponding parts of the wave. At the middle of a hollow they are in a vertical line, and are depressed from the still water position, being closer together the nearer they are to the surface.

* It is evident that the profile of such waves will be of trochoidal form.

When the crest of the wave passes they are again in a vertical line, but they are raised above their still water position, being further apart the nearer they are to the surface. In the intermediate positions, between the hollow and crest, the line they are in bends toward the crest in such a way that its inclination to the vertical at the top is at each instant practically equal to the slope of the wave at that point—that is, to the inclination of the surface of the wave to the horizon. The still water positions corresponding to the lines *a b c*, etc., being at equal distances apart, the shapes inclosed between these lines and the surface of the wave indicate the change in configuration undergone by a block of water as the wave passes. It is very important to observe this change, as the motion of any body, such as a ship, floating on the wave, must naturally be largely influenced by it, the water tending of course to carry the body with it.

Suppose a ship to be floating broadside on among waves such as we have described; where they are long, compared with the draught of water of the ship, we may consider that to the depth of her draught below the surface the particles of water practically revolve in circles of equal radii. Neglecting for the present the action of the water upon the ship, due to the change of configuration it undergoes as the wave passes, the forces acting upon her are exactly the same as those which would act upon her in still water, combined in each case with the centrifugal force with which the particles of water at the surface are revolving—for the pressure exerted by the water upon any point of the surface of the ship is the resultant of the pressure which would act on this point in still water, combined with the centrifugal force with which the particles of water are rotating, and so on over the whole of her immersed surface. Hence the resultant pressure of water upon the vessel is the resultant effect of the pressure which would act on her in still water, combined with the centrifugal force, and it acts (by a well-known principle in hydrodynamics) through the centre of buoyancy perpendicular to the the wave at this part. Also the centre of gravity of ship describes a circle, as each wave passes, of practically the same diameter as the particles of water in contact with her surface, so that she exerts an equal and opposite pressure upon the water. Hence we have nearly the same forces acting on the ship as there would be in still water, only that they act in a direction constantly normal to the wave surface, and she will have a tendency to keep normal to the wave surface, which will nearly equal her tendency to keep upright in still water,* and if she be inclined from this normal, the same couple, practically, tends to restore her to it as in still water would tend to restore her to the upright if she were inclined from it by the same amount. Ordinary ships will not, however, keep normal to the wave surface. We have already referred to one cause tending to prevent this †—viz., the change in the configuration undergone by the water relatively to the wave surface. This is modified by the ship's inertia, which tends to make her perform oscillations about the normal to the wave surface in the same periodic time as in still water. The action of the waves, however, is such that the vessel is compelled to perform these oscillations in the same time as the waves. Thus we may regard the rolling of a ship among waves as made up of the motion she would have supposing she always kept normal to the wave surface, combined with the oscillation she performs about the normal to the wave. ‡ The tendency to keep the ship normal to the wave surface is called *stiffness*, while the tendency to keep her vertical is called *steadiness*.

With the supposition we have made, neglecting also the resistance of the water, the exact differential equation of the motion of the ship may be written down, and though it has not yet been solved, a very approximate equation has, and from it we gather the following results, which are verified by experience :—If the radius of gyration of the ship and the height of the metacentre be such that her time of *unresisted rolling in still water* is the same as the time of the waves, each roll of the ship as she is passed by successive waves will be increased in amplitude by a constant amount varying directly as the maximum slope of the wave, so that but for the friction of the surface, and the resistance to motion offered by the keels, sharp parts of the floor, etc., the ship must eventually roll completely over, no mat-

* This tendency was pointed out by Mr. Froude, in 1861. It was the first great step towards our present knowledge on the rolling of ships

† At sea there are many causes tending to do this ; such as variations in the force and direction of the wind, irregularity in the shape of the waves, etc.

‡ In dealing with the safety of ships among waves, their extreme inclination to this normal must be taken.

ter to what angle she may possess stability, or how small the waves may be; and the more nearly her time of unresisted rolling in still water approximates to the time of the waves, the more nearly will this result be approached. From this we infer that in designing it is desirable to arrange so that the ship's time of unresisted rolling in still water may be as long as possible, in order that she may not be likely often to meet with waves of her own period.

We have already, in dealing with ships rolling in still water, explained the nature of the resistance to rolling offered by the water, arising from the fact that part of the force tending to make the ship roll is expended in setting in motion large volumes of water through the medium of her keels, skin resistances, etc. This is equally true in the case of the ship among waves, besides which the motion of the water relatively to the wave surface may not be neglected, the tendency of the ship to follow this motion offering considerable resistance to her rolling. The nature of this action is very apparent from what we have said of the motion of vertical columns of water during the passing of a wave.

Let us consider the two following extreme cases:—1st. The case of a flat board, such as A, floating on the surface of the water; this we may consider a form of unlimited stability—it follows the wave surface. 2dly. That of a thin weightless board, B, of no stability, floating so that it would be vertical if the water were at rest—it follows the motion of the particles of water of the originally vertical columns, and therefore, as we have seen, its inclination to the perpendicular at any instant is approximately the same as the slope of the wave at that point, and therefore the same as the inclination of A to the horizontal, supposing A and B to occupy about the same position on the wave. We observe that the wave surface as it moves along tends to turn A in the direction indicated by the small arrow above it, but the originally vertical column of water in which B floats tends to turn B in the opposite direction, so that these two actions are of a conflicting character; and if we were to secure B to the under side of A perpendicular to it, they would evidently undergo an intermediate motion. This is just the case with a ship—the action of the waves upon that part of the ship between wind and water is opposed to their action upon the keel and sharp parts of the floor; the combined effect being a tendency on the part of the waves to make her take an intermediate course, as shown at C.

It would be dangerous to attempt to make a ship roll like the flat board on the surface of large waves, as might be done approximately, by making her stability very great, concentrating the weights at the centre of gravity, and increasing her breadth, for by so doing we should only reduce her *time of unresisted rolling* in still water so that she would be frequently falling in with smaller waves among which she would roll very considerably. A ship may be made to roll like the board in the second case, *with* the originally vertical particles of water, by making her periodic time of unresisted rolling in still water, divided by the period of the waves, equal to $\sqrt{2}$. In this case the ship is upright at the middle of the hollow between two waves, and on the top of the crest, and there would be a like result if she were to roll like the flat board on the surface of the water. In both of these cases the angle through which she rolls is evidently the same as the maximum slope of the wave.

If her periodic time of unresisted rolling in still water be *less* than the $\sqrt{2}$, the upright positions occur before the arrival of the hollows and crests, and if greater, after the arrival of the hollows and crests; in the first case the maximum angle of heel of the ship is greater than a certain quantity, the height of the wave divided by the diameter of a circle whose circumference is equal to the length of the wave, but in the second case it is less than this quantity.

Thus on the whole we see it is desirable to lengthen the time of unresisted rolling in still water as much as possible. This, as we have already pointed out, may be done by lengthening the ship's radius of gyration and decreasing the distance between the centre of gravity and metacentre. The radius of gyration may be increased by weighing out the weights—that is, by placing them as near the sides of the ship as possible without lowering them. Considerable facility is afforded for doing this in a war vessel in the disposition of the armor and guns, by placing them well out on the sides as far from the middle of the ship as possible. The distance between the centre of gravity and the metacentre may be diminished by raising the centre of gravity—that is, by raising the weights bodily.

This we may do only to a very limited extent, for the tendency which the ship exerts to keep upright, and to return to the upright when inclined, depends both in amount and in the extent of the angle of inclination on the lowness of the position of the centre of gravity.

We have supposed the vessel to be rolling broadside-on to the waves; if she be in motion and her course be inclined to the direction traversed by the waves instead of perpendicular to it, the apparent time of the waves relatively to the ship must be taken in dealing with the question of her rolling—that is, the time that elapses between the passing of two successive crests or hollows. Thus the effective wave period may be varied very considerably by changes in the direction and speed of the vessel.

Our present knowledge of the rolling of ships among waves is largely due to the labors of several of the members of the Institution of Naval Architects, and in dealing with the subject our object has been to condense the results of their investigations and make them intelligible to the general reader. At the first meeting of this institution, March, 1860, Dr. Woolley, who read a paper "On the Present State of the Mathematical Theory of Naval Architecture," expressed his regret that so little reliable information was possessed on this subject. Since that time, however, it has been so thoroughly dealt with, at least so far as theory is concerned, that it would seem that little more can be done except in the way of experimental investigation.

## ANCIENT MINING—THE GRECIAN MINES REOPENED.

From the "Mining Journal."

### THE MINES OF LAURIUM.

Erichthonius was king of Athens 1,400 years and more before Christ, at the time when the great Sesostris commanded the armies of Egypt in Syria, Mesopotamia, Armenia, and Asia Minor, and Moses led the Hebrews into the Wilderness of Sin. Then were first discovered the silver-lead veins running between the mica schist and limestone formations of the promontory of Laurium, stretching from Cape Sunium to Athens. So Pliny says. From its mountain tops, 1,000 ft. high, the spectator beholds the peaks of Eubœa, the Isles of the Cyclades, the Bay of Salamis, and the shores of Argolis, as far as the heights of Lacedæmonia, Corinth, and the steeps of Arcadia, all that theatre in which was played the immortal drama of six centuries, from the departure of Xerxes to the arrival of the Goths.

Under the government of Themistocles each of the 20,000 free citizens of Athens received 10 silver drachmas annually as a State tax of 4 per cent on the total product of the mines, which, therefore, must have amounted to 4,800,000 drachmas, or £175,000. The residue of the Athenians, 280,000 in number, were slaves, and got nothing. The mines were worked by slaves. Thirty years later, Pericles built with the silver of Laurium the Parthenon and other splendid monuments of Athens, and made abundant preparations for the long and costly Peloponesian war. The State leased mining rights which were perpetual, alienable, and transmissible by will, for sums varying from one to two talents (£220 to £440), and the operators hired slaves even from Macedonia and Thrace. There was a "metal court" and "metallic laws" to settle contested boundaries, underground riots and contests, the robbing of pillars, and the improper driving of adits and galleries to the injury of neighboring rights.

The war broke out. Laurium became a marked point of strategy. The coast was ravaged, the mines stopped up. Then the invading allies were driven off and the mines re-opened, and the Athenian mint resumed its wonted activity. But the Syracusan expedition failed, and Attica received a death wound. Finally the traitor Alcibiades induced the Spartans to make thorough work with Laurium. The mining regions were again invaded, conquered, desolated; 20,000 slaves revolted and fled. Athens fell.

After the return of Thrasybulus, some attempts were made to reorganize the mines, but their prosperity never returned. Their skilled labor was scattered; the mining and metallurgical traditions were lost; the sources of capital were dried up. Xenophon indeed wrote a work on "Revenue," devoting a whole chapter of it to the mines of Laurium, proposing the opening of new

veins, a co-operative enterprise by the ten tribes of Athens, and the fortification of the mining districts in view of future wars. And his counsels were listened to. For awhile wealth again flowed into the city. But in the first century of the Christian era a grand revolt of the slave miners, who were most inhumanly treated by the operators, quenched the entire industry in a sea of fire and blood, never again to be revived until 18 centur es had elapsed.

In Strabo's time, 10 to 15 B. C., the veins of metal were accounted to be exhausted; and all that was attempted was to smelt the debris or refuse heaps of former times. No doubt this meant only that the workings had reached what was to the Greek engineers an unprofitable depth. There is no good reason for supposing that with steam-hoisting machines and pumps, gunpowder and ventilating fans, the argentiferous lead veins would not be more productive now than ever they were in the palmy days of Pericles. Six slaves accomplished no more work than one of our free miners with the aid of powder and steam. Their only tools were an iron pick with a flat head, and a little chisel, made of round iron drawn to a point. Yet with only these they sunk and drove several thousand shafts and galleries, and excavated piecemeal enormous chambers in the marble and tough mica schist. The most ancient works communicate with the surface by long inclined gangways; but subsequently the mining grounds were reached by vertical pits sometimes 350 ft. deep, always square (usually 5 ft. by 6 ft.), with smooth sides, and furnished with offsets for ladders at regular distances. In this vast labyrinth of abandoned works the marks of the tool are as fresh as if made yesterday, and the tools themselves, dropped at the signal for revolt, are found lying on the heaps of fall. The galleries along which the files of hod carriers took up their wretched march to and fro, are methodically marked by little piles of stones, long since cemented together by stalactite concretion. Ancient lamps are found in niches, black with ancient smoke. And near the bottoms of the pits rude sketches made in the wall with a pick, mark temporary resting places of those who climbed the ladders or posts of underground foremen who regulated their order of ascent. But not a lamp now shines, not a pick is heard, not a ghost of all that crowd of half-naked and half-desperate workmen remains to tell the tale.

When the mineral reached the surface it was sledged to pieces and picked. The leaner ores were pounded fine in mortars of iron or hard stone, and washed to increase its fineness. The washing troughs are very numerous; many of them are covered over with cinders of a subsequent age when the tailings were exploited instead of the mines. They are quadrangular basins, lined with cement, connected by channels, the whole forming squares of 35 or 40 ft. on a side. In the midst is a horizontal area slightly inclined. The gudgeon holes of a jigging machine are to be seen in the sides of one of these basins, the others serving only to receive the washed ore of greatest density and richness. Water was evidently precious, for it was collected in great cylindrical or quadrangular cisterns, excavated in the rocks and cemented, holding from 3,500 to 16,000 cubic ft. Rock-cut stairways served the workmen for cleaning out the pools.

Enormous mounds of tailings exist around the mountains, holding 6 to 7 per cent. of lead, and from 3½ to 4 oz. of silver to the ton. The foundries were ordinarily placed near the mines, but some were on the seashore, at Thorico, Cypriano, Ergasteria, Pacha, and Lagrana. Others were distributed among the villages of the interior, now called Megala-pephka, Berzeko, Sinterini, etc. Some of the furnaces have been disinterred from beneath mounds of scoria. They were low cylindrical hollow stones of mica schist or trachyte, about 3 ft. in diameter, heated with charcoal from the neighboring forests, or brought from the mountains of Macedonia and Thrace, and blown with (goatskin) bellows worked by hand. High chimneys were built to carry off the noxious gases.

The products of fusion were: 1. A lead matt holding from 50 to 100 oz. of silver to the ton; 2. Scoria; 3. Oxide of zinc, which condensed in the chimney or on the furnace walls in layers, and was sold to the physicians. The matt was then cupelled under a current of air, the lead oxidized to litharge, and the silver button left in the bottom of the crucible. Pliny calls the litharge "scum of lead." It was sold, partly revived, making an impure lead, and manufactured into clamps, tubes, vases, cramps for masonry, and white lead paint.

The centuries rolled on. Pirates by sea and bandits by land destroyed mines, manufactures, and commerce together. Normands, Sicilians, Catalans, Venetians, Ge-

noese, and Turks by turns prevented all possible return to industry. Chateaubriand in 1806 found in all the Laurium peninsula but one poor hamlet of 800 souls. In 1863 the district was headquarters of bandits obedient to a little king called Kytzos.

One evening in May, 1863, two gentlemen, one French the other Italian, owners of mines in Spain and Sardinia, and heavy merchants of Marseilles, landed from a coasting boat on the long-deserted beach of ancient Ergasteria, at the head of a lovely mountain-locked harbor, having Helena's Isle as a breakwater in front of it. With the practised eye of men accustomed to the search of metalliferous deposits, they perceived the value of the mounds of debris which the old miners had rejected, and then and there, without further delay, they entered into negotiations with the Parèdre and Chinôtis, or village headman and his council. They found that some of the property was in dispute between the village and the Government. However, they completed the purchase with the village, determining to make it right with the Government afterwards. A treaty of purchase was formally made, and the whole village turned out to celebrate the event in rejoicings and festivities. The explorers returned to Athens, highly delighted with their prospects. Count Amelot, at Athens, arranged that the Government rights should not stand in their way. They deposited £400, the full value of Government claims, with the Treasurer of State. M. Fiedler, sent by the Greek Government in 1837, and M. Riessegger in 1842, had pronounced the Laurium district worthless. But the new comers had discovered refuse heaps concealed beneath the soil, where no one dreamed of anything valuable being concealed. They received a concession, or mining right, covering 2,500 acres, or six square miles, comprising about the 1-20th part of the metalliferous surface of Laurium. The concession included the right of exploring the ancient mines, and the right to the silver lead ores in their neighborhood.

In less than two years they created one of the grandest lead foundries in the world. The traveller can take the company's steamer "Laurion" at the Pirœus of Athens, and find in the harbor of Ergasteria a fleet of Greek, French, and English vessels; 1,000 ton colliers from Newcastle; here a steamer from Marseilles unloading machinery, tools, wagons, rails; there the Greek blockade-runner of Cretan notoriety; all about, lateen sail craft from every part in the Archipelago laden with legumes, fruit, and fish; and some from Lagrana landing scoria. On shore, to the left, range three great sheds, under which blaze the furnaces, in front of which run serpent-like streams of black lava, or modern cinder, which a crowd of half-naked workmen pry up, break off, and convey two-thirds of a mile away, in wagons by a tramroad, round to a southern shore of the bay. From the fusion sheds runs what looks like an aqueduct on arches, the gallery for condensation of the fumes, ending in a chimney mounted on an isolated hill, 4,700 ft. distant. Between the sheds are the blowing-engines, constructed in Marseilles, and roaring night and day. To the right are the store-houses, superintendent's office, free hospital for workmen, stables for 300 horses, and a populous village, dominated by a many-colored Greek church, in which almost every figure and custom in Europe may be seen.

To bring the materials of manufacture from heaps scattered over a district having a radius of from 6 to 10 miles, about 45 miles of perfectly macadamized roads diverge from the port, cross the ravines by substantial bridges, and ascend the slopes. They are almost the only roads existing in good order in the kingdom of Greece; 300 horses draw down in wagons every day 400 tons of scoria to be washed, enriched, and smelted over again; and the works could handle more than they receive. It takes 5 tons of debris to give 1 ton of mineral proper for fusion. The colossal waterworks are capable of washing 500 tons a day. Finally, a railroad (of 3 ft. 4 in. gauge and 6 miles long) is undertaken to reach the most important of the debris mounds in the valleys of Camaresa and Berzeko, on the other side of a watershed, 450 ft. high, through which it passes by tunnel. Eighteen months sufficed for its construction, and three powerful Mulhousen locomotives draw trains of 110 tons, over gradients of 26 to 1,000 in 6-ton wagons built at Lyons. The rails were rolled at Bességes; the repair shop, machine, tools, got up by Bouhey, in Paris. But the two steam-engines for the washing grounds, of 90-horse power each, made in Belgium, were not transported to Greece because the wretched Government of this worthless little country took advantage of the German invasion of France to inaugurate a reactionary policy towards these foreign regenerators of

home manufacture worthy of the worst days of the worst and most unhappy countries.

The sudden conversion of a desert into a source of such vast wealth excited the cupidity alike of the Greek Government and of the brigands to whom it grants protection. Kytzos demanded £2,000 as the price of leaving the Company alone, but was fortunately killed before he could enforce his demand, and Spagnos, who succeeded Kytzos and Arranitakis, since of melancholy notoriety, also attempted on one occasion to seize the Director-General of the mines, and finally a pitched battle was on the point of being fought between a Greek company and the Franco-Italians, which was only averted by the arrival of troops from Athens. Public feeling at last got so worked up in Greece at the sight of a number of foreigners exporting their mineral wealth and pocketing the profits, that the Government was forced to pass a law declaring all scoria and debris of old mines Government property and giving the law a retrospective effect, on the strength of which they claimed not merely an exorbitant tax from the Laurium Company for the future, but a sum of £80,000 for back payment for the eight years before the law was made. This the Company naturally refused to pay, and the diplomatic agents of the two Governments found themselves compelled to interfere to protect their subjects from so extortionate a demand. The Greeks continued more obstinate as they perceived the richness of the prize won by the foreigner, the value of which was estimated by their own official reports at a milliard of francs. The Company in despair, after the events of the last two years have so completely crippled the power and influence of France, of being able to continue to work her property in security, offered at last to sell for £560,000 to the Greek Government what the latter valued at a milliard. An agreement to this effect was made with Komoundorous, then Prime Minister, and he promised to bring in a Bill authorizing the sale. At the last moment, however, he perceived that no such Bill would be carried, and attempted to postpone it. The King would not permit this breach of faith, and Komoundorous, rather than face the inevitable defeat which it would entail, resigned. He was succeeded by Deligeorgis, who has written a memorial defending the law, and receding from the agreement of his predecessors. He has proposed, indeed, to abolish the law, and let the question be tried by the Judges; but this is a manifest absurdity, as the dispute only arises out of a law which would then not exist, so that the question itself would fall to the ground. Meantime, the French and Italian Governments are both beginning to lose patience. There is no doubt that under the Empire France would not have tolerated for a day the action of the various Greek Cabinets, whose ruin the Laurium question has successively involved in this matter; and there is a limit even to French patience just now, while the Italian Government is rising into a position of such European importance that it may not be loath to take advantage of the occasion which is thus afforded of asserting with a strong hand the justice of its claim.

All that remains to add to this already extended notice of the Laurium enterprise are the statistics of work done. Nothing is handled which contains less than from 8 to 12 per cent. of lead. When properly mixed, the materials are charged with coke into cylindrical fires 4 ft. 8 in. high, blown with fans. The cinder which escapes below still holds from 2½ to 3 per cent. of lead; 2 per cent. more is carried off in fumes. The residue is drawn off twice a day in pigs marked "Ellas." This bar lead (very antimonious) contains only from 10½ to 14 oz. of silver to the ton. A part of it is refined at the works and marked "Fos." Both brands are sent to England in exchange of coal. No cupellation is attempted at Ergasterial. Each fire passes 30 to 35 tons of scoria per day, and 12 of the 18 fires are in blast night and day. The annual product is 9,000 to 10,000 tons of lead, which is almost equal to half to the entire make of France.

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Western River Levels.—The Mississippi river is 2,616 miles in length, and is 1,680 ft. above the level of the Gulf at its utmost source. At St. Paul it is 660 ft. above the Gulf level; at the head of Rock Island Rapids, 505 ft; at St. Louis, 407 ft.; at Cairo, 322 ft; at Memphis, 221 ft.; at Natchez, 66 ft.; at New Orleans, and at the head of the passes, 2 ft. 9 in. Arkansas rises 1,514 miles from its entrance into the Mississippi, and 10,000 ft. above the Gulf; at Fort Smith, 418 ft.; at Little Rock, 252 ft.; at its mouth, 162 ft. The Missouri rises 2,908 miles from its entrance into the Mississippi, and 6,800 ft. above the Gulf level; at Fort Benton it is 3,815 ft. above the Gulf; at Sioux City, 1,065; and at St. Joseph, 756 ft. The Ohio is 609 ft. above the Gulf at Pittsburgh, and 532 ft. at Cincinnati.

# THE SEWAGE PROBLEM.

From "The Engineer."

The fact that a committee of inquiry into the whole question of the utilization of sewage was appointed some time ago by the British Association was probably due to two causes. One was the desire on the part of the Association to arrive at a true solution of a question so important, and the other the opinion entertained by many, that the report of the Rivers Pollution Commission was exceptionally severe upon some of the methods which had been put forward as affecting the result as yet unattained. In furtherance of this object a sum of money was appropriated to the purpose, and the members of the committee at once commenced their labors. Before proceeding to draw the attention of our readers to the numerous instructive and interesting details which characterize the last report of the Committee on the Utilization of Sewage, it may be stated that it confirms the views we have always held on the subject, and with consistency expressed in our columns. One of the most novel principles of treating sewage on the irrigation plan is that introduced about two years ago at Merthyr Tydvil. This especial method of downward filtration we have already designated under the title of "cubical irrigation," inasmuch as the depth of the soil acted upon by the sewage becomes an important element in the operation, and the term also serves to distinguish it from the ordinary or superficial irrigation. The great advantage of this method is that but a small area of ground comparatively is required to effect the purpose. It must be borne in mind that the term "utilization" of sewage is rather a misnomer when applied to cubical irrigation. This treatment does certainly purify and render innocuous the sewage, but does not economize or make use of its valuable manurial properties to the same extent as superficial irrigation. It is unquestionably rather a plan for the purification than the utilization of sewage. There is one fact which was elicited by the inquiry at Merthyr Tydvil, which is unfortunately but too common. A comparison of the quantities of sewage and of the effluent water proves that the latter is more than double the former, and a careful investigation further showed that the rainfall was not sufficient to account for the very large increase. Whence, then, did it come? Observations subsequently revealed that it was due to the river, and that a complete system of percolation existed in the soil between the river and the drains. To set the matter beyond a doubt trial holes were dug in a field in the vicinity of the filtering beds, and it was found that the same thing occurred. When the water rose and fell in the river there was a corresponding variation of the level of it in the holes. It is easy to imagine in what condition the water supply of the town must be if the inhabitants are in the habit of having recourse to wells. One can realize the statement so frequently made, that in such cases the people do not pump water, but sewage.

The plan of deodorizing sewage and precipitating solid matters carried on at the Union Workhouse of Stoke, was the subject of one of the many inquiries of the committee. From first to last, charcoal is the filtering agent employed in the process. A very curious phenomenon was observed in this instance, and one exactly the reverse of that which took place at Merthyr Tydvil. The quantity of sewage gauged amounted to 5,000 gallons, while that of the effluent water only reached the total of 2,000 gallons. Where the remainder went is a mystery. The charcoal, as proved by analysis, absorbed a large portion of it, but nothing in proportion to the quantity that escaped somewhere or other. What also renders this result somewhat anomalous is that there must have been some dilution, which nevertheless had no effect in increasing the quantity of the effluent water. That the suspended matter should be removed is only what is to be expected from any description of filtration, especially when conducted upon a scale so limited as that of a workhouse containing not more than 750 inmates. A corresponding reduction in the amount of the ammonia and organic nitrogen would also be looked for. So also would be the result, which was that no oxidation took place, no nitrates or nitrites were discovered in the effluent water, which was to all intents and purposes a dilute sewage, and "had a strong smell of sewage." Although the process adopted at the locality in question is evidently utterly unfit for an extended application, yet it

must not be supposed that all the deodorizing and disinfecting methods are limited to so narrow a range of operation. That they do not, in our opinion, fulfil those conditions which are essentially requisite in any scheme for the complete and profitable utilization of sewage, is a subject to which no reference need now be made. It will be seen as we proceed that the committee give the preference to irrigation as the mode best calculated to effect the desired object. From what has been already stated with regard to cubical irrigation, it might be assumed that it was not adapted to the purpose; but it must not be forgotten that it is intended always to employ it in conjunction with the ordinary or superficial irrigation, otherwise the plan will not answer the expectations formed of it. It is evident that the soil cannot be made at one and the same time a mere filter bed and a prolific producer of vegetables and crops. Saturation must sooner or later be the result of continuous downward filtration. It is for this very reason that wherever it is possible this system must be carried out on the intermittent principle, which, combined with deep subsoil drainage, will accomplish a great deal in preventing the saturation that would otherwise ensue. The obvious preventive against saturation is taking care to acquire a sufficient area of land upon which to distribute the sewage—a condition becoming daily more and more difficult to comply with. Without wishing to assume at present that the irrigation principle is able to solve the sewage problem by effecting the two indispensable results, viz., the purification and utilization of the sewage, there is no necessity to advance arguments to prove incontestably that hitherto the other methods have not been able to accomplish that double object. Let us take Ealing for example. Two systems of deodorization and precipitation have been tried at that place. The first consisted in causing the sewage to pass into depositing tanks and afterwards through a filtering medium 7 ft. in thickness. The plan failed to purify the sewage to the extent required. The effluent water was not of a quality fit to be discharged into a stream or natural watercourse. The second attempt to deal with the matter was made under the auspices of General Scott, whose principle is well worthy of attention. It does not pretend to accomplish what many other methods do, either with respect to purifying the sewage so as to allow of it being discharged into a river, or to rendering it suitable as an artificial manure. It is nevertheless possible that this last result might be obtained. The peculiarity in the process in question is, that if the dried material or sludge, as it is called, should be too poor in manurial value to obtain a marketable price, and if it should also be of no use as a cement, it can be burned away—consumed without any risk of a nuisance being established. One of the difficulties attending this process, and one which attends all of a similar character, is that of drying the sludge. This is a known difficulty in the A B C process, of which it may be remarked that it must be very discouraging to those who advocate its adoption, that no tangible evidence of its success at Crossness has been forthcoming.

Passing on to sewage farms, there is a great deal in the report of the committee to encourage those who give the preference to irrigation over all other matters for effecting the utilization of sewage. We have frequently adverted to the absolute necessity of attending strictly to two principal points. One is deep draining, and the other the proper and scientific laying out of the ground. Farmers have yet a great deal to learn in this respect, and some of the failures that have attended irrigation on a small scale are undoubtedly due to the ignorance and prejudice displayed by those who undertook the carrying out of that which they knew nothing about. The sewage farm at Earlswood is an instance in which these essential details have been altogether ignored, and the consequence is that neither is the land benefited by the sewage, nor the sewage purified by the land. These two operations are, in fact, one, and the successful performance of the one is a guarantee for that of the other. As a corroboration of our remarks with regard to the necessity for underdraining, the case of a field of beans, grown on the sewage farm at Tunbridge Wells, may be quoted. One portion of the crop was heavy and healthy looking, and the other very poor and stunted, and, notwithstanding this manifest difference in the quality and quantity, the whole field had been uniformly flooded with sewage. The reason, however, for the circumstance became clear upon a little further inquiry, when it was elicited that the part of the field upon which the superior crop was grown had been underdrained to a depth of

4 ft., while no such an operation had been carried out in the other part of the field. It is to be hoped that the practical nature of this test will be duly appreciated by all those who may in future be engaged in sewage irrigation. A hint as to the value of sewage as a simple irrigator may also be taken from the fact that on the same farm a large field of turnips was discovered to be infested with the fly. The field was at once flooded with sewage, the fly destroyed, and the crop saved. If we sum up the conclusions arrived at by those who listened to and discussed the various papers and reports read at the last meeting of the British Association relating to the sewage question, they will be found to be almost unanimous in favor of the irrigation principle.

Without wishing to assert that an artificial marketable manure cannot be prepared from deodorized and precipitated sewage, yet some attention must be given to those who are the best judges on the matter. These are the farmers, who buy manure, natural and artificial. They state that deodorized sewage is not only worthless as a manure, but positively injurious to the present crops and to the land as well, having regard to the future crops to be raised on it. There was a great deal of good sense and truth in the remarks made respecting the action taken by the Government in sewage matters. We have already expressed our own opinion on this point, and shown that unless Government takes some measures to help local authorities out of their difficulty, instead of thwarting them and throwing obstacles in their way when they are endeavoring to do that which is right, there is no use in attempting to utilize sewage on the irrigation principle. The case of West Ham is a prominent one. The local authorities were willing to expend a considerable sum of money in carrying out their object, but the Government refused their consent to the plan. Their refusal was based upon the report of an inspector sent down by them, who was a well-known opponent of sewage irrigation. The whole inspection was therefore a mere farce, the case having been virtually prejudged and antecedently decided upon. There are other well-known instances which could be adduced in evidence. In spite of cubical irrigation, which has to some extent diminished the "land difficulty," that still remains the great obstacle to sewage irrigation. Our own opinion is that the land can be obtained. Land is obtained for railways and other purposes which partake a good deal more of the nature of an expediency than necessity. The health and sanitary welfare of the public are of infinitely more importance than rapid transport from town to town. It is not too much to assert that whole districts are depopulated in order to obtain land for our city railways and streets, and yet not an acre can be obtained in the open country for the purpose of relieving the inhabitants of large towns from one of the most serious and dangerous evils that a nation ever had to deal with.

## ON THE INCREASING SPIRAL IN HEAVY RIFLED ORDNANCE.

By COMMANDER W. DAWSON, R. N.

From the "Journal of the Society of Arts."

Rotation is usually imparted to elongated projectiles by means of ribs, studs, or other projections, which, in their exit from the gun, traverse suitable parallel grooves or slots, cut to receive them in the bore, at an angle with the axis of the piece proportioned to the desired rapidity of spin. When the angle which the slots make with the axis of the gun is the same throughout, uniform spirals are the result; but when the angle becomes greater towards the muzzle, the grooves form curves known as increasing spirals. If the bore be conceived as laid open like a flat surface, the uniform spirals will appear as straight lines, the "uniformly increasing spirals" as parabolas. Each point in those parabolas makes a different angle with the axis of the gun, and would impart, if possible, a different amount of rotation to every part of the projectile. As, however, a rigid iron cylindrical body cannot have every point in its length rotated at different speeds, one "driving" point, or ring of "driving" points, is selected in rear of the centre of gravity, on which the whole effort of rotation is concentrated. A second ring of "guiding" points before the centre of gravity, being made to fit the grooves very loosely, tend to check any extraordinary deviation from the prescribed route. By a strange hallucination, even in the uniform spiral "Woolwich" guns, the effort of rota-

tion is concentrated on two soft non-centering points in each groove, instead of being diffused over a long iron centering bearing extending along the whole cylindrical body of the projectile. Of the 19 rifled guns now in the naval service 13 have uniform spirals, which complete one turn in 20, 30, 35, 36½ 37, 38, and 40 calibres; four have their grooves cut as "uniformly increasing spirals," beginning as parallel straight lines at their origin, progressing as parabolas, and ending at the muzzle with one turn in 35, 40 or 45 diameters; whilst two guns have a compromise between the two forms of spiral, the grooves beginning as curves of one turn in 100 calibres, and ending at the muzzle with one turn in 40 or 50 diameters. This diversity of twist aptly illustrates the guesswork which obtains as to the proper angle of spiral, and as to the consequent rapidity of spin necessary to insure stability of flight. Experiments were made in 1864-65, to determine the influence of various degrees of twist with uniform spirals upon the initial velocities, from 6.3-in., 7 ton, "shunt" guns, but no notice is recorded of the corresponding stabilities of flight. From these it was ascertained "that the velocity increases as the amount of twist decreases, up to a certain point, viz.: one turn in 50 (? 40) calibres, where the velocity is greatest; it then commences to diminish. The loss of velocity in the higher twists is probably due to increased friction in the passage of the projectile through the bore. The diminution of velocity in the case of the low twist is most likely owing to the projectile not being retarded sufficiently to admit of the complete combustion of the charge." The initial velocities were :—

| Spiral of Gun. | Charge. | Shot. | Calculated mean initial velocity. | Charge. | Shell. | Calculated mean initial velocity. |
|---|---|---|---|---|---|---|
| calibre. | lbs. | lbs. | feet. | lbs. | lbs. | feet. |
| 1 turn in 20 | .. | .. | .. | .. | .. | .. |
| 1 " 30 | 16.926 | 84.625 | 1520 | 10.499 | 83.4 | 1124.5 |
| 1 " 40 | " | " | 1535 | " | " | 1124.5 |
| 1 " 50 | " | " | 1533 | " | " | 1137.2 |
| 1 " 60 | " | " | 1514 | " | " | 1126.3 |
| 1 " 80 | .. | .. | .. | .. | .. | .. |
| 1 " 20 | 14.625 | 71 9 | 1526 6 | .. | .. | .. |
| 1 " 30 | " | 72 | 1540.6 | 8.395 | 83.4 | 997.3 |
| 1 " 40 | " | 71.6 | 1553.4 | " | " | 995.6 |
| 1 " 50 | " | 72 | 1562 | " | " | 992.1 |
| 1 " 60 | " | 71.7 | 1550 | " | " | 988.9 |
| 1 " 80 | " | 71.8 | 1521 | . | | .. |

To know what effect the angle of uniform spiral has on stability of flight, the chief object for which rifling is adopted, we must turn to Sir Joseph Whitworth, who has worked out experimentally the relation between the length of the projectile, expressed in diameters, and the rapidity of twist, as it affects the polygonal iron-bearing centering system. This was tried with a 1 ft. gun of about 1¼ in. calibre, firing 25 oz. charges at 3 in. elevation. It was found that one turn in 34.35 calibres gave perfect spin to shot 3 diameters in length; that one turn in 15.26 calibres spun shot 6 diameters long perfectly; and that one turn in 7.13 calibres sent shot of 7 diameters perfectly true and point first. These results have been verified as regards several angles of spiral in larger calibres, so that Sir Joseph Whitworth now recommends one turn in 18 calibres for heavy guns, which is capable of giving perfect rotation to projectiles 5 diameters long; whilst the French or "Woolwich"non-centering short-bearing system gives, with one turn in 35 calibres, only a wabbling, waltzing, movement to shell of 2½ to 3 calibres.

No experiments exist as to the influence of various degrees of final muzzle twist upon the initial velocity, nor upon the stability of flight, in the case of spirals the angles of which increase rapidly at the muzzle. The amount of spin is, in these cases, determined by the well-known formula familiarly called "the rule of thumb."

The professed object of introducing, in 1865, increasing spirals for the stronger and heavier wrought-iron coil guns, was the supposition—1st, that the projectiles would slip away more rapidly from their seats next the powder chambers than when uniform spirals were employed; 2d, that these assumed quicker commencing velocities would considerably reduce the maximum powder pressures in the chambers; and 3d, that this supposed great relief to the chambers would prolong the lives of guns.

Now, here are three distinct guesses, each one of which is opposed to experience :—

1*st*. In the heavy gun competition of 1863-5, where all the conditions, except the rifling projections and grooves, were identical, Scott's uniform spiral 7 in. gun projected its iron-bearing flanged-centring 110 lbs. shot from its muzzle 59 ft. faster, inflicting a muzzle blow 133 foot-tons heavier than the similar French, or, as it is now mis-called, "Woolwich" gun, with increasing spiral and studs, the report stating that "the

French system has decidedly the lowest velocities." Again, 1865, two 7-in. guns were rifled with the same final angle of twist, on the French or "Woolwich" system; one with uniform and the other with increasing spiral; and the latter gave 21.2 ft. less initial velocity, and 56 foot-tons lighter muzzle blow. The Professor of Artillery at Woolwich mentions in his "Modern Artillery," the case of an 8-in. gun which gave, with uniform spiral, 35 ft. more initial velocity, and 116 foot-tons heavier muzzle blow than its increasing spiral competitor. Against these facts we have guesses, but not a single experimental datum.

2*d*. The Committee on Explosives have recently discovered that the maximum powder pressure is relieved when the shot has moved one-quarter of an inch in its seat when using rifle large grain powder, and 6 in. when using pebble powder. They have not discovered that the shot moves through the first quarter of an inch of its motion quicker with either the uniform or the increasing spiral of the same final angle; nor is it at all likely that they ever will do so. But they have found that the gun in its rifled state sustains somewhat less powder pressure than when firing the same charges as a smooth-bore. If, then, any difference of maximum pressure in the chamber can at any future time be proved to obtain between the two forms of spirals having the same final angle, it is difficult to foresee in favor of which it will be found, but we are justified in assuming that it will be so infinitesimal as to be rather a curious philosophical phenomenon than a practical consideration for artillerists.

3*d*. If we regard the shot in its seat as a valve moved by internal pressure, it is quite evident that the maximum pressure which is relieved by that motion cannot extend outside the position of the base of the projectile at the moment when that pressure is registered. In other words, all the evil effects upon the gun due to the direct action of the maximum powder pressure must occur either in the charge chamber or within a quarter of an inch of it, if using R. L. G. powder, or within 6 in. of it with pebble powder. The only exceptions there can be to this rule, are when the lateral wriggling or vertical hammering action of the wabbling projectile causes a momentary obstruction, and the area of the maximum powder pressure might naturally extend to the point where the jam occurs; or, when the projectile breaks up, and the pieces become permanently wedged in the bore, inflicting a blow which causes the gun to burst explosively, as has repeatedly occurred. When, then, the shot is free to escape, the life of the gun is not materially affected by differences of powder pressure within the possible limits which could obtain, under any rational supposition, between guns rifled with the same final angle of twist on the uniform and on the increasing systems. There is now in use in Woolwich a 10 in. 18-ton gun, having 18 in. holes bored right through its walls, for crusher gauges, which has fired in that state several hundred 60 to 87½ lb. charges with 400 lb. projectiles, and has sustained maximum pressure of 60 foot-tons, being within 3 tons of as great a strain as that sustained by the 35 ton gun in firing its heaviest (130 lbs.) charge with a 700 lb. projectile; yet, we are told that the interior of that mutilated gun has not suffered from these excessive powder pressures. An 8 in. gun of only 6½ tons weight, instead of 9 tons, with 16 in. holes through its walls, has similarly withstood hundreds of rounds of 35 lb. charges and 185 lb. projectiles, though its proper battering charge is but 22 lbs. with 115 lb. projectiles, without any internal injury from powder pressure.

So far, then, as the advantages claimed for the increasing spiral are concerned, they are pure guesses opposed to facts; and it is, as to those points, a matter of indifference whether it or the uniform spiral be adopted. But, on this baseless hypothesis, we are sacrificing in vital questions the efficiency of our great guns, for the increasing spiral necessitates the concentration of rotary effort on a single point in each groove, this point being represented by a gun-metal stud 1.45 in. in diameter, projecting .195 in. outside the projectile, and wedged into an under-cut hole 16 in. in diameter, and .3 in. deep. Imagine, then, attempts to rapidly rotate an iron cylinder, 12 in. in diameter, 34.45 in. long, and nearly a third of a ton in weight (700 lbs.), by a ring of nine such studs placed a few inches behind the centre of gravity. Lateral wriggling, vertical hammering, a wabbling forward motion in the bore, with waltzing gyrations, "puffing" noise and "unsteady" movements in the flight, lessened muzzle blow, and reduced range, are the natural results. To overcome these, reduced length and weight of projectile are, in all the larger calibres, vainly resorted to, with permanently crippled effi-

ciency. More rapid twist, and consequent more perfect rotation, cannot be given, because the six-tenths limit of bearing which the increased spiral necessitates will not endure the greater effort. The sacrifice of shell-power has, therefore, been all in vain. Within the last three years six heavy guns are known to have been permanently disabled on shipboard by their own projectiles, whilst firing at targets; and five others are known to have been temporarily disabled for some hours from the same cause. How many more naval guns have been compelled to cease fire for hours has been kept secret. But when two 18-ton guns were so disabled on board the Hercules in 1870, the Director-General of Naval Ordnance officially remarked that "the crack in the A (inner) tube, and the strained condition of the B (outer muzzle) tube over the crack, *are exactly what I should have expected.*" And a critical examination of these suicidal injuries shows that they almost invariably occur near the muzzle, where the shot in full flight meets with enchanced resistance from an increasing angle of spiral. The fact that two of the suicides had uniform spirals is sufficiently accounted for by the absurd notion which obtains of rejecting the great advantage it offers of employing a long iron-bearing, extending over the whole cylindrical body of the projectile, and of applying it in the form of strengthening ribs cast with it, instead of a short bearing concentrated upon weakening stud holes.

The "cemetery of suicides" at the Royal Arsenal has had several interesting specimens added to it since the introduction of increasing spirals with short soft bearings, some of which illustrate other forms of self-destruction incidental to the French or "Woolwich" system. First in order comes the father of the system, the competitive "Woolwich" 7 in. gun already referred to, which after 567 rounds had so battered its bore and spiked its upper groove by the blow of its front upper stud, that it was ordered "*to be fired under 'precaution'*" against bursting; whilst the rifling of the Scott uniform spiral gun with iron ribbed

| Date. | Place. | Gun. | | Self-inflicted Injuries. | Cessation of Fire. |
|---|---|---|---|---|---|
| 1865 | Shoeburyness... | 9-in. | 7 ton | Upper groove cracked by stud, dented and enlarged tube | Permanent. |
| " | " | 9-in. | 12¾ ton | Much worn by gas after 315 rounds | No. |
| " | " | 9-in. | 12⅔ ton | Cracked grooves and bust, 400 rounds | Burst. |
| " | " | " | " | Cracked tube, disabled, 1,049 rounds | Permanent. |
| 1868 | Tegel, Berlin .. | " | " | Cracked tube, disabled, 311 rounds | Permanent. |
| " | Woolwich ..... | " | " | Explosive burst, by projectile jamming, 1 round | Burst explosively. |
| 1869 | *Bellerophon*..... | " | " | Grooves overridden by studs | Permanent |
| " | *Reduving*. ..... | 7-in. | 6½ ton | Muzzle split | Permanent. |
| 1870 | *Favorite*. ..... | " | " | Grooves overridden by studs | No. |
| 1869 | Shoeburyness.. | 10-in. | 18 ton | Grooves burred, bore dented, tube split, 534 rounds | Permanent. |
| " | *Hercules*. ..... | " | " | Muzzle split 43 rounds | Permanent. |
| " | " | " | " | Vent damaged, 46 rounds | —hours. |
| 1870 | *Staunch*..... | 9-in. | 12⅔ ton | Bore dented, grooves bored, gun disabled | Permanent. |
| " | *Royal Sovereign*. | " | " | Bore deeply cut into | —hours. |
| " | *Warrior*. ..... | 7-in. | 6½ ton | Bore dented, and had to be filed down | —hours. |
| 1871 | *Bellerophon*..... | 9-in. | 12⅔ ton | Bore dented | No. |
| " | " | " | " | Bore considerably scored by gas. 165 rounds | No. |
| " | " | " | " | Muzzle coil split | Permanent. |
| 1870 | Shoeburyness | 7-in. / 68 pr. | 95 cwt. | Burst violently into 76 pieces, shot jammed, 1 round | Burst explosively. |
| " | Aldershot ..... | 9-pounder, bronze | | Grooves worn away, etc., disabled, 243 rounds | Permanent. |
| " | " | " | " | " " " " | Permanent. |
| " | " | " | " | Grooves worn by studs, " | No. |
| " | Shoeburyness... | " | " | Grooves overriden by studs, bore expanded | Permanent. |
| " | " | " | " | " " " " | Permanent. |
| " | *Monarch*..... | 12-in. | 25 ton | Grooves slightly burred in four guns, average 35 rounds each | No. |
| 1871 | Shoeburyness | 7-in. / 68 pr. | 95 cwt. | Grooves enlarged near origin | No. |
| " | Woolwich..... | 12-in. | 35 ton | Lower groove cracked by stud from 12 to 25 in. of origin, 68 rounds | No. |
| 1872 | *Bellerophon*..... | 9-in. | 12⅔ ton | ? Bore dented, had to be filed down | —hours. |
| " | " | " | " | " " " | —hours. |
| " | *Royal Oak*.... . | 8-in. | 9 ton | Bore dented by projectiles | No. |

projectiles was as perfect after the last (417th) round as when it left the factory. The Woolwich "Infant" of 35 tons, though not yet committed to the Cemetery of Suicides, was spiked in the lower grooves by its lower rear stud, from 8 to 20 in. outside the point to which the maximum powder pressure extends, in the effort to rotate a 700-lb. projectile upon $9\frac{6}{10}$ in. points, under the propulsion of 120 lbs. pebble powder charges. With a uniform spiral and Scott's iron-flanged shell, 100 lbs. of powder would have sent the same weight to the useful fighting range of 1,500 yards with the elevation required when using 120 lbs. charges at present. Then there is a $12\frac{1}{2}$ ton gun, in which a shot breaking up through its stud holes wedged itself, causing a fearful explosive burst, on 25th September, 1868. A converted 68-pounder, of 95 cwt., met with a fearful accident on the 10th August, 1870, flinging 76 pieces over an area of 580 yards by 150 yards. Though this latter gun had not an increasing spiral, its 114 lb. projectile was balanced on a couple of weakening studs in each groove, which is not much less fatal with uniform than with increasing spirals. The "Cemetery of Suicides" is hardly more instructive than the Ordnance Inspector's reports of abrasions, and enlargements and erosions, and other injuries of guns not permanently disabled, these maladies being either caused or aggravated by the studded system, which an increasing spiral necessitates. Of eight Lancaster 95-cwt. guns having increased spirals sent to the Crimea, three blew their own muzzles off; but once rid of that portion containing the increased strain, one of these guns did good service without its muzzle. Of 42 Parrott guns with increased spirals used at the siege of Charleston, 23 committed suicide —General Gilmore reporting that the increasing strain thrown on the muzzle was the offending cause. Lancaster and the Americans both abandoned the increasing spiral, and now it destroys only British guns, with the eminent risk of some day destroying also British gunners.

There is a most instructive sphere of artillery study at present locked up, which might be opened with great advantage to science, as well as to the public service, if some member of Parliament would move for a "Return of all guns which, since 1865, had been obliged to cease fire, temporarily or permanently, owing to self-inflicted injuries; the nature and position of such injuries, and the period which elapsed before fire could be resumed. Also for a return of all guns which, since 1865, had sustained internal damages of a less disabling character, and the nature and position of such injuries." We should then be in a position to trace out, in each case, the maladies of British guns, and, knowing the cause, be a long way towards suggesting the remedy. Meanwhile, the ablest artillery officers are of opinion "that there are disadvantages in the "Woolwich" system, and a better system of rifling might be found." That there must be ample matter for a lengthy official return is evident from the examples of the suicidal effects of "Woolwich" studded projectiles, given in the table on the preceding page.

## F. C. WEBB ON AN ELECTRICAL EXPERIMENT WITH AN INSULATED ROOM.

From "The Philadelphia Magazine."

The object of the author's experiments was to show that the ordinary theory of the action of the Electrical Machine is incorrect. Some years ago the author endeavored to prove by reasoning that the ordinary explanations given of the discharge of a charged conductor by communication with the ground was erroneous; and suggested an experiment with an insulated room as a means of proving the fallacy of these ordinary explanations of discharge, etc. The extracted results are best given in the author's own words.

It is generally stated in books on electricity, that when an electrical machine has its rubber to earth, on the action of the machine the prime conductor becomes charged positively, and the equal quantity of negative electricity which is generated is lost in the earth, and that when the prime conductor is then placed in contact with the earth, its discharge is merely the consequence of its sharing the electricity with the earth, the proportion remaining on the conductor being, in virtue of the almost infinite size of the earth as compared with

the conductor, almost infinitely small, and consequently quite inappreciable. When, therefore, the ordinary experiment of charging the prime conductor is performed in an insulated room, according to the theories which I deny, the negative electricity being unable to share itself with the earth, some differences in the effects produced should be attained. The negative electricity, for instance, if it tends to flow to the earth, should influence an electrometer placed in contact, and exterior to the room. Again, if the room is connected to the earth during the charging of the prime conductor and is afterwards insulated, the prime conductor, if touched to the room, ought not to be discharged, since it can only share its electricity with the room, instead of with the almost indefinitely large surface of the earth. Now, I argue, that when electricity is produced, at any rate by artificial means, the negative and positive are not only always produced in equal quantities, but remain each as much in abeyance as the other, and that complete discharge always consists in the recombination of equal quantities of opposite electricity. Thus when a conductor is charged, say, positively from a plate-machine having the rubber connected to the earth, the negative electricity has no tendency to flow to and distribute itself equally over the earth, but distributes itself principally on the nearest conducting surfaces to the positively charged surface; and when the surface to which the negative pole is attached entirely bounds the dielectric which separates it from the positively charged surface, the negative electricity is entirely distributed on that surface, none flowing to any other part of the earth. When these are joined by a conductor, discharge occurs through the recombination of the exactly equal quantities of electricity previously produced.

For carrying out the experiments a room was constructed about 8 ft. by 9 and about 8 ft. high. The floor was of wood, and the sides of wooden framework, covered with calico, and with pieces of tinfoil pasted about it, to make it a good conductor. It had a door and two windows of wire gauze. A small table was placed in it, and a frictional electrical machine was placed on this. The room was suspended by four double parts of half inch round gutta-percha band to a wooden frame, the floor being about 4 ft. from the ground. The gutta-percha was covered with paraffine, and the whole room was tested for insulation with a delicate astatic Thomson reflecting galvanometer, and gave no perceptible loss. A Peltier electrometer was placed on the ground outside, and a wire from the brass knob of this was connected to the gauze of the window. The table was connected with the tinfoil that was pasted about the surfaces of the room, so that when the rubber or prime conductor was connected to the table it was in connection with the sides of the room. Thus arranged, the machine acted to all appearance exactly the same as in uninsulated room.

When the rubber was connected to the table, on turning the glass disc, the prime conductor was charged so as to give off sparks the same as when the room was uninsulated; and the conductor was completely discharged when touched to the insulated room. Not the slightest effect was produced on the electrometer, even when sparks were flashing from the prime conductor to the wire gauze of the windows to which the wire from the electrometer was attached. Connecting the room to the earth made no difference. A sphere about a foot in diameter was then charged, when the room was insulated, and then handed out by an insulating handle, when the electrometer immediately diverged to about 50 deg., showing that the outer surface of the room had become negative. On taking the sphere back into the room, the electrometer fell to zero. It is impossible to reconcile these results with the explanation of the action that takes place in charging and discharging as given and republished in most works. Take, for instance, the following from Noad's "Student's Text-Book:"—"Thus, in order to get any development of electricity, there must be either with the rubber or with the prime conductor, electrical communication with the earth, as the great natural reservoir of electricity."

According to the views I have advocated, the accumulation on the prime conductor depends on the resistance of what I have termed the inductive circuit, which, in the case of charging the prime conductor, with the rubber connected to surrounding objects, consists simply of the resistance of the dielectric separating the prime conductor from the surrounding objects, and is therefore the same whether the room is connected to earth or not.

Dr. Ferguson, in his "Electricity," seems

to have a tendency to discard the older explanations; but at times his explanations appear to be incomplete; thus he says:—

"We have hitherto taken no notice of the—E, that, for instance, is said to be lost in the ground when glass is charged positively. Now it may be lost, and the—E induced by the glass on surrounding conductors may be new—E induced by it. But it is also possible, nay, even probable, that this—E is none other than the—E said to be lost. If this be the case, the ground acts as much on the glass as the glass on the ground; and the action is precisely the same as in a galvanic circuit, when the polarization proceeds in opposite ways in two opposite directions, the action of the one strengthening the action of the other." Dr. Ferguson adds: "However, it makes no practical difference, and it is simpler to suppose the insulated body to be the one centre of force." With this last paragraph I cannot agree, as it will be found that, by considering problems of electrostatics by means of the theory of inductive circuits, many can be solved which cannot be explained by an allusion to the earth as a common reservoir. The experiment with the insulated room is only one of them. I maintain that no electricity is ever lost in the ground or drawn from the ground as a reservoir. All electricity generated, if we consider it as a quantity, is produced in equal quantities, and can only be neutralized by en equal quantity of electricity of the opposite name. Thus, when the sphere in the insulated-room experiment was charged positively from the prime conductor, an equal quantity of negative went to the room. When the sphere was taken out of the room, this negative went to the outside of the room at the same time that the external conductors to the room became polarized, so that there remained on external objects a charge of negative opposing the positive on the sphere, and a charge of positive opposing the negative on the external surface of the room. By connecting the sphere to the earth, the sphere's charge and its opposing charge on surrounding objects neutralize each other, leaving the room negative to a positive charge in the earth, which, when touched together, neutralize each other. Or if the sphere is touched to the room, the positive of the sphere neutralizes the negative on the room, the negative and positive charges in surrounding objects at the same time recombining also. Or when the sphere was taken back into the room, the negative returned to the inside of the room, the positive and negative which were induced on external conductors by the sphere and room when the sphere was external to the room recombining.

Circumstances prevented Mr. Webb from carrying out a more complete series of experiments, but the experiments made seem sufficient to show the fallacy of the generally accepted theory of the Electrical Machine.

## EXPERIMENTS WITH DYNAMITE AT LLANBERIS.

From the "Mining Journal" (London).

A series of highly interesting experiments with dynamite took place on Wednesday at Llanberis, under the direction and superintendence of the committee appointed by Government to report on the safety, stability, and general character of gun cotton, dynamite, lithofracteur, and other explosives.

The first experiment was intended to show the extraordinary power of dynamite when exploded with a percussion cap. A piece of exceedingly tough wrought iron, cut off the end of the shaft of a steam engine, 15¼ in. in diameter by 9 in. in thickness, had a hole drilled through it 1⅜ diameter, which was filled with dynamite and exploded by a percussion cap fixed at the end of a Bickford fuse. The quantity of dynamite used was about 1 lb., and the two ends of the bore hole were left open without any tamping being used. On the explosion taking place the mass of iron was blown into two pieces, with a clear rent the full 15¼ in. in length, One of the pieces was blown 10 yards distant, where it struck against the side of the quarry, and the other half was blown a distance of 12 yards on to a bank 12 ft. high.

2. About ⅝ lb. of dynamite was put into a wooden tube, covered at the end with a piece of ordinary sheet tin, and placed 15 in. from an iron girder 2 in. thick, and on

being exploded, small portions of the tin perforated the iron to the extent of $\frac{1}{2}$ in. in depth.

3. A solid piece of wrought iron, 9 in. square, was placed on the ground, and 5 lbs. of dynamite was put on the top of it in an open cylinder of thin sheet iron without being closed, and on the explosion taking place, the wrought iron was considerably compressed, and split into two pieces.

The above experiments having sufficiently illustrated the extraordinary power of dynamite when exploded by the detonations of a percussion cap, further experiments were made to test its safety in case of accident from concussion or fire. For this purpose the following experiments were made:

4. A 56-lb. case of dynamite, in its ordinary packing as imported, was dropped down a quarry 60 ft. high, and fell to the bottom without breaking the case, or doing any damage whatever.

5. A similar case was then thrown down another quarry from a height of 130 ft.; the case was broken into small fragments, and the packages of dynamite were broken open, and the powder scattered about, without the slightest explosion taking place.

6. A 56-lb. case of dynamite was placed at the bottom of a quarry, and a large box filled with sand and slate rubbish, weighing between 2 and 3 cwt., was allowed to fall on it from a height of 60 ft. The case of dynamite was completely smashed, and the contents scattered about, without any appearance of explosion or fire.

7. The chief experiment of the day was intended to show the result which might be expected in case a magazine of dynamite were to take fire. A magazine of wood, 8 ft. square, covered with felt roof, similar in all respects to those being erected by the British Dynamite Company, at their manufactory at Ardeer, had 12 of the cases of dynamite containing together 6 cwt., placed in it, with a large quantity of shavings and wood with petroleum, and was set fire to. The magazine burned with a considerable flame for about 25 min. until the dynamite caught fire, and then threw out an exceedingly fierce red flame for 12 min., when it exploded with great violence, making a very loud report, and leaving a hole about 5 ft. deep on the peaty ground where the magazine had stood.

8. A case of 56 lbs. had a small hole made in it, through which a Bickford fuse was inserted, and the box was turned with the fuse downwards, and on being set fire to, the whole of the dynamite burned away without any explosion taking place.

9. A packet containing 6 lbs. of dynamite was placed in a $\frac{3}{4}$-in. deal box, nailed down, placed on a quantity of shavings and wood in a close corner of a quarry and covered with slate rubbish; a large slab of slate being placed on the top. The wood was then set fire to, and after burning for about half an hour the dynamite caught fire, and burned quietly away without any explosion taking place.

The result of these experiments appeared to give general satisfaction. The extraordinary power of dynamite was aptly illustrated by the fracture of the solid piece of wrought iron, some of the committee expressing beforehand the opinion that the quantity of dynamite used could not be expected to fracture so strong a mass of iron.

The fourth, fifth, and sixth experiments were conclusive to show that dynamite is quite safe from explosion from ordinary concussion, and the eighth and ninth showed that it may be set fire to, and will burn in reasonable quantities without any explosion whatever, while the seventh experiment was conclusive to show that in storing large quantities in magazines the usual and ordinary precautions applicable to all explosives ought to be adopted, since dynamite, like all other explosives, when set fire to in large quantities, and in close magazines, may be expected to explode. Some of the committee, while expressing their surprise that so large a quantity of dynamite should burn so long as 12 min. before exploding, gun cotton having under similar circumstances in the experiments near Hastings exploded in as many seconds, stated their satisfaction that it did explode, and showed the numerous quarrymen who were in attendance that ordinary care ought to be adopted in its use, and that they ought not to burn it with perfect impunity.

The necessity for such a lesson is shown by the fact that after the dynamite had been burning full 10 min., and just before its explosion, one of the quarrymen was anxious to go close to it, and was with difficulty restrained from doing so.

# THE BATTLE OF THE GAUGES RENEWED—RAILWAYS OR NO RAILWAYS.*

From "Engineering."

Some months ago General G. P. Buell, the Chief Engineer of the Texas Pacific Railroad, sent in to his Directors a report advocating the adoption of a 3 ft. 6 in. gauge for that line, and pointing out at the same time the advantages of the narrow gauge generally. The undertaking being an unusually large one, however—the proposed trunk line being 1,500 miles in length—Mr. Marshall O. Roberts, the President of the railroad, did not feel justified in deciding unadvised upon the gauge which was to be adopted, and he accordingly submitted General Buell's report to the Hon. Silas Seymour, of New York, with a request that he would state his opinion on the matter. Under these circumstances a counter report was made by Mr. Seymour, in the course of which he reviewed the arguments in favor of narrow gauge, but arrived at conclusions diametrically opposed to those advanced by General Buell. It is this "Review" of Mr. Seymour's with which Mr. Fairlie deals—and which we may add he demolishes—in the work before us, of the contents of which we now propose to speak.

Inasmuch as Mr. Seymour's "Review" has probably been circulated to but a very limited extent in this country, Mr. Fairlie has adopted the plan of dealing with it paragraph by paragraph, quoting each paragraph, or group of paragraphs, relating to one division of the subject at the head of his comments upon that division. This arrangement is an exellent one, as it not only places both sides of the question clearly before the reader, but also does full justice to Mr. Seymour's arguments, and renders it impossible for that gentleman to complain of injustice having been done him by partial quotation from his writings. And we may say here that we fully agree with the remark made by Mr. Fairlie in his introduction, that Mr. Seymour has evinced every disposition to treat the subject he has attempted to review fairly; but he has evidently written with but an imperfect knowledge both of the theory of narrow gauge and of the practical results which have already been obtained by its adoption. Mr. Seymour may, in fact, be taken as an able representative of an important class, who, having positions which make their opinions heeded, denounce narrow gauge progress, not from any desire to be unfair, but simply because they do not take the trouble to inform themselves of fact and practical details which would alone enable them to arrive at a just conclusion. As an able reply to the arguments advanced by this class of opponents, Mr. Fairlie's book is calculated to do good service, while it possesses additional value from the fact that it contains a summary of information concerning narrow gauge lines such as has never before appeared in so compact a form.

General Buell, in his report on the Texas line, when comparing the 4 ft. 8½ in. and 3 ft. 6 in. gauges, claimed as the advantage in favor of the adoption of the latter, that the cost of its road-bed would be to that of the broader gauge as 100 to 130; and the cost of its superstructure as 100 to 145; that it would permit of the attainment of the necessary speed of 35 to 45 miles per hour; that the cost of the necessary equipment of rolling stock would be as 100 to 150, or 100 to 155; and that in working, the percentage of dead weight to paying load would, on the narrower gauge, be about $\frac{47}{100}$ against $\frac{75}{100}$ on the broad. These advantages Mr. Seymour will not admit, but he adds that even if any one of the advantages above stated can be proved, General Buell will have gained his case.

Passing over his preliminary arguments, we find Mr. Seymour endeavoring to ascertain the comparative relative cost of earthworks, etc., on broad and narrow gauge roads, by assuming that a formation width of 12 ft. will do for a line of 4 ft. 8½ in. gauge, and one of 10 ft., for a line with a gauge of 3 ft. 6 in., and then reducing the prism representing the section of the embankment or cutting for the broad gauge, by taking a 2 ft. slice out of the middle. Mr. Fairlie of course at once demolishes this argument, and not only points out the errors in Mr. Seymour's reasoning, but brings forward facts deduced by Mr. Carl Pihl's practice in Norway, and other practical experiences elsewhere, to upset Mr.

* The Battle of the Gauges Renewed. Railways or no Railways. Narrow Gauge, Economy and Efficiency v. Broad Gauge, Costliness with Extravagance. By Robert F. Fairlie. London: Effingham Wilson, Royal Exchange. [Price 2s. 6d.]

Seymour's conclusions. As our author justly states, "an average mile of properly designed narrow-gauge road, ready for grading, is not an average mile of standard road with a piece cut out of the middle." In this sentence we have the whole gist of the matter, and until those who theorize upon the broad and narrow gauge question thoroughly understand this, their arguments must go for little or nothing.

Proceeding next to the consideration of the cost of superstructure, Mr. Fairlie shows that Mr. Seymour has treated General Buell unfairly, by assuming that the General claimed an economy of 45 per cent. of the cost of the broad gauge, whereas what he really did claim was a difference of 45 per cent. of the cost of the narrow, or about two-thirds as much. Taking the latter basis, Mr. Fairlie proceeds to show that General Buell is correct in his statements, the details of the various items of cost being fully worked out. And here Mr. Fairlie takes the opportunity of pointing out the differences between narrow gauge and "light" broad gauge lines, explaining why the latter cannot be so economical as the former, and exposing the fallacious reasoning which has frequently been advanced on this subject. Here again, too, we find facts brought forward to support theory, Mr. Fairlie quoting the details of Mr. John Fowler's estimates for the alternative light 5 ft. 6 in. gauge and 3 ft. 6 in. gauge lines between Kotree and Moultan; these lines, which were laid out over the same ground, and with the same weight of rails, showing, in the total cost of construction and equipment, a saving of £846 per mile in favor of the narrow gauge.

Turning next to the rolling stock, we find Mr. Fairlie pointing out the influence which the employment of the Fairlie engine exerts upon the traffic-accommodating capabilities of the narrow gauge. We have ourselves pointed out in this journal on several occasions that the most intimate connection exists between the full development of narrow gauge lines and the employment of Mr. Fairlie's locomotives. As far as the carrying stock goes, it is simply a question of additional length of train to make the loads hauled on the narrow gauge equal those hauled on the broad. A broad-gauge line will carry a certain load per foot run of train, and a narrow-gauge line, with lighter rails, a certain less weight per foot; and this being so, all we have to do is to make the lengths of the trains in the inverse proportions of these weights per foot, to get the same aggregate load in the two cases. When we come to the engine, however, the case is different. With the narrower gauge the ordinary type of locomotive becomes crippled to a greater or less extent. The width of fire-box and size of boiler become limited, and hence, also, the power the engine is capable of developing. With the Fairline engine, on the other hand, there is no such reduction of the capacity, consequent on the reduction of gauge, the manner in which the boiler is carried and the position given to the fire-box between the two bogies, rendering it possible to get any desired amount of heating surface and fire-grate area even upon lines of extremely narrow gauge, while the freedom of motion given by the double bogie system enables the engine to adapt itself perfectly to the sharp curves which frequently form special features in economical narrow-gauge railways.

The question of the relative weights of the carrying stock on the narrow and broad gauges, and the proportions between the dead weight and paying loads which will be found to exist in the two cases, are very ably and fully dealt with in the work before us. Taking Mr. Seymour's statements as his text, Mr. Fairlie proceeds to disprove those statements, and in doing so gives an exhaustive summary of the practical experience relating to the subject which has been gained by English, American, and Continental engineers. In dealing with the question of dead weight also, we find our author giving due prominence to the important fact, that to insure economical working the capacity of the carriages or wagons employed must be specially adapted to the requirements of the traffic; and in directing attention to this fact he shows very clearly that with the narrow gauge vastly greater facilities are afforded for fulfilling these conditions properly. Indeed, the "adaptability" of narrow-gauge lines and their rolling stock is one of their most distinguishing characteristics.

We now come to the single point in which Mr. Seymour and Mr. Fairlie are in agreement, this being that the objections to a break of gauge are generally overrated, a view which we have ourselves advanced on several occasions. In connection with this subject, some interesting facts are given re-

specting the cost of transferring freights on different lines where breaks of gauge occur, and the valuable experience of General McCullum on the Erie Railway is also quoted.

One of the arguments advanced by Mr. Seymour in favor of the broader gauge is that it enables larger wheels to be used, and these wheels reduce the tractive resistances of the trains. Speaking broadly, Mr. Seymour is, of course, correct; but Mr. Fairlie is not content with broad statements, and taking the sizes of wheels actually used on the two gauges, and the data as to the resistances of trains afforded by the valuable and exhaustive experiments of MM. Vuillemin, Guebhard, and Dieudonné, he shows that the "very material saving," claimed by Mr. Seymour, amounts to but 4 per cent. at very slow speeds, while it is reduced as the velocity of the trains increases, until at the very moderate speed of 20 miles per hour, it has dwindled down to a miserable $\frac{3}{4}$ per cent. The reduced resistances on curves due to the narrower gauge are also duly considered by Mr. Fairlie, who deals with the subject in a very clear way.

The concluding portions of Mr. Seymour's review are interesting, as containing some records of American practice and experience; but they cannot be considered to bear directly upon the matter under discussion, and Mr. Fairlie dismisses them with a few brief comments, of which we need not speak further here. Having finished his detailed analysis of Mr. Seymour's "Review," Mr. Fairlie next preceeds to adduce further facts in support of his views, and after quoting from this journal our account of the Festiniog Railway and its rolling stock, he gives an interesting *resumé* of M. Nördling's recent work, "Stimmen über Schmalspurige Eisenbahnen." In this book M. Nördling has collected some most interesting statistics and general data respecting the results obtained with the numerous narrow-gauge railways already working—facts which we commend to the earnest attention of all interested in this subject. M. Nördling, we are glad to find, holds opinions identical with our own as to the value of the Fairlie engine for working narrow-gauge railways, and he expresses an earnest hope that such a line worked by Fairlie engines may be constructed in Austria.

Following the *resumé* of M. Nördling's book, we have some additional data respecting the actual working of narrow-gauge lines, collected by Signor Biglia, the well-known Italian Engineer, and next we have a summary of Mr. Fairlie's own views on narrow-gauge lines and the mode of working them. In enunciating his views Mr. Fairlie gives full prominence to the objections urged against his engines, and then replies to these objections in detail, and we must say that he has most decidedly the best of the argument, and that he has dealt with the subject justly and in a true spirit of moderation. We shall not reproduce his arguments here, because we can not quote them at length, and they most decidedly deserve to be read in their entirety, and to be read, too, after considering the arguments to which they form replies.

In connection with this part of the book Mr. Fairlie gives a series of heliotype illustrations showing a number of engines and varieties of rolling stock constructed from his designs for different railways; but these illustrations, although interesting as reproductions of photographs of actually constructed engines and rolling stock, certainly do not give us a high opinion of the process by which they have been produced. They remind us, in fact, more of very indifferent lithographs printed in sepia-colored ink than anything else, and we almost regret that they should have been introduced into a book otherwise so well got up.

The summary of Mr. Fairlie's views, of which we have just spoken, although forming the conclusion of what may strictly be called the "Battle of the Gauges Renewed," is not the end of the work. It is followed by an interesting account of the Denver and Rio Grande Railway, from the pen of Mr. Samuel Bowles, and after this comes "A Reply to Mr. Ramsbottom's Report against the Principle of the Fairlie Engine." This "reply" refers to a report made by Mr. Ramsbottom and Mr. W. P. Marshall, on some engines constructed on Mr. Fairlie's principle, but not from Mr. Fairlie's designs, for the Queensland railways, and in it our author decidedly gets the best of the argument. The "reply," however, can only be justly appreciated by its perusal as a whole, in connection with the diagrams which illustrate it, and we shall not therefore speak of it further here.

We now come to the concluding section of Mr. Fairlie's book, which consists of a collection of diagrams, showing the weights and capacities, etc., of the rolling stock in

use on English and foreign lines of various gauges, and the proportions of dead weight and paying load, in passenger and goods trains, on these various lines. These diagrams, which are accompanied by explanatory matter, have evidently been compiled with great care and with a vast expenditure of time and trouble, and they not only afford, in a compact form, an enormous amount of valuable information, but they also illustrate, in a most striking manner, the truths of many of the arguments which have been advanced in favor of narrow-gauge railways.

Altogether Mr. Fairlie's book forms a most valuable contribution to our literature treating of economical railway construction, and its author deserves especial thanks for having placed such a vast amount of information at the disposal of the public in such a cheap and readable form. The construction of cheap lines of narrow gauge has become one not merely of engineering, but of general public interest, and it is, therefore, especially important that the facts relating to such lines should be laid before general readers in a way that may enable them to be universally understood. This Mr. Fairlie has done, and done well, in the work we have reviewed.

## ON THE FORCE OF THE RUDDER, WITH A READY WAY OF CALCULATING THE SAME IN HORSE POWER.

By HENRY RANSFORD, Esq, ASSOCIATE.

From the "Journal of the Society of Arts."

Several papers have been read before this Institution on different kinds of rudders, and referring also to the great force of the rudder, with the difficulty of controlling that force in large ships; but there are still two or three matters connected with the subject requiring further investigation, and from which useful information may be derived.

Putting the helm down, and altering a ship's course, say from north to south, compels her to perform half a revolution, by revolving on a centre within herself, her wake showing, at the same time, she has passed along an irregular semicircle; this effect, we know, is caused by the water impinging on the rudder with a force in proportion to the rate at which the vessel is moving.

This centre, or point of the keel on which a vessel revolves, is very difficult to determine. I am disposed to think that when a ship is said to be in good trim, about the centre of the floor (taking its length and breadth) is her point of gyration; but if not in trim, the longitudinal centre of her gravity or total weight (if I may so express it), becomes the point, and I confess I do not see a way to determine it exactly.

The main thing, however, is, that a ship has a centre on which she pivots in obeying the action of the rudder, and one in particular in which she obeys that action better than when that centre is changed; and, as a rule, this action is much further from the stern-post than the stem, thus giving the rudder a longer lever to exert its force in guiding the ship, regarding that turning-point as a fulcrum.

The longer the ship the greater the power required to turn her round; hence it is important to know the whereabouts of her centre of gyration, and what excess of lever the rudder has to act on to overcome the forward resistance; because, while (say) her starboard side from this centre to the stern is turning and forcing the water one way, her port side from the centre to the stem is turning and forcing water in the opposite direction.

Take for example a ship of 300 ft. long, if her revolving centre is only 130 ft. from the stem, then the rudder has a leverage of 170 ft. to overcome the forward resistance, and she probably steers easily; but if, on the contrary, her centre of gyration is much nearer to the stern-post, she will be found to steer badly, and the suggestion, as a remedy, would probably be to increase the size of the rudder, although altering her trim might produce a better result.

A vessel at anchor in a tide-way takes a sheer very quickly, because, if she has a pivoting point, then it must be the outer edge of the hawser pipe, and the flowing tide quickly adjusts any displacement of water. To calculate the power of a rudder guiding a ship, the depth of water she draws has to be considered, as well as the force of current

created by the speed. A ship drawing 26 ft., displacing water at her keel of a pressure of 13 lbs. on the square inch, we cannot wonder if a difficulty is found in steering her, but the mean of that depth gives a pressure equal only to 6½ lbs. on the square inch that the water bears on the rudder, which, forced against it at the vessel's speed per hour, is the actual power of the helm.

In ascertaining this amount of force, the area of the rudder has also to be taken. A large iron-clad is fully 150 ft., which may be got over to an angle, making it equal to a square of 50 superficial feet, dragged through water of an average resisting power of 6½ lbs. on the square inch, at the rate of 10 knots per hour; the power required to do that is the force executed by the rudder in turning such a ship round when going at that speed.

Thinking it desirable that the amount of this force should be estimated in horse-power by some easy method, not being a mathematician myself, I applied to others, but they were unable to solve the problem; I have, therefore, worked it out in my own fashion, and I should be glad if any scientific gentleman present would point out if it is erroneous. I start with the data proposed in a paper I read last year, that was not contradicted—viz., that no floating body can move through water without sending the displaced water to the surface; and finding from reports of trial-trips that vessels in turning usually lose at least one-sixth of the speed they were going in a straight course, that proportion has been adopted. Take a ship drawing 26 ft., going 12 knots per hour; rudder 150 ft. area put over to an angle of 30 deg., which in water I consider would be equal to 50 ft. square, at a medium depth of 13 ft., and reduce speed to 10 knots; one knot in 6 min. equal to 1,012 ft. per min. This would be equal to raising a volume of water 1,012 ft. long, 10 ft. by 5 ft., 13 ft. high in a minute.

1,012
50

50,600 cubic feet
6

303,600 gallons of water
10

3,036,000 pounds of water

Watts' calculation, 32,000 pounds of water raised one foot per minute = 1 H.P.

32,000 pounds ÷ 10 = 3,200 ÷ 13 = 247 gallons raised 13 per minute.
303,600 gallons ÷ 247 = 1,289 H.P. force of rudder.

Taking into consideration that the lower part of the rudder is much broader than the upper part, some of the largest iron-clads have a force of 1,400 H. P. at a similar angle, hence the difficulty of putting the helm down.

This amount of force will probably astonish many who have not gone into the question. A ship the length of the Warrior, 380 ft., taking her centre of turning at two-fifths from the stem, has to displace a volume of water 26 ft. deep, equal to 2 semicircles, one a radius of 152 ft., the other 228 ft., whenever her head is turned half round the horizon, or from north to south; the power to accomplish this displacement in 6 or 7 min. must be very great.

Swinging a vessel round in a quiet dock is found to be a very slow and laborious process, even with a powerful and well-manned capstan. If, then, it requires this amount of power to turn these large ships round in fine weather, it is not difficult to understand why in bad weather, making but little headway, occasionally they will not answer the helm at all; or that it was found next to impossible to get the head of the Great Eastern round, when during the heavy gale in which she was disabled, she rolled helplessly in the trough of the sea for so many hours.

I once saw the Minotaur in the Channel off Portland, under sail alone, in a moderate breeze; she might have been going 5 knots, when she went about. We did not time her by the watch, but it was the opinion of three or four who were looking at her that she was in stays over a quarter of an hour. The helm could have had no power the last 10 min., it was only the two forward topsails aback that at length got her round.

When a vessel has bilge-keels—those very questionable appendages to prevent rolling—there is another force acting against the power of the rudder. A large ship so fitted, lying over at an angle of 15 deg., brings the leeward one to a perpendicular at a depth of some 20 ft. below the surface of the water, offering a great resistance to the turning of the ship; that, with equal area, would be equal to the power of the rudder, were the speed of the rotary motion equal to the forward one; but I find from the report of many trial trips, that the

speed of the former is not more than 1-16th of the latter or forward one.

Should any advocates of bilge-keels doubt their resistance to the turning of a ship, let them take a plank 20 ft. long and 15 in. deep, weighted to float edgeways level with the water; then make fast one end, and with a rope drag on the other, until the plank has made a half-circle; knowing that force, then calculate how much would be required to turn 180 ft. long 20 ft. below the surface. The result will be instructive.

Having termed bilge-keels as questionable appendages, to prevent rolling, I do so for this reason—that a ship does not of herself roll in the water, but with the water or wave in motion. A ship is comparatively still; a heavy wave comes on, lifting her up sideways, and passing under her, the vessel rolls over to her other side, sliding down the receding wave into the hollow between it and the next one; when, if another wave did not follow on, she would soon remain still, having gained her equilibrium or perpendicular.

Although a landsman, I have repeatedly watched vessels rolling, both in rough and very heavy weather. A moderate sea on the beam or quarter lifts the ship in the direction she is going; but a heavy beam sea appears to strike the ship low down, lifting her up with the deck inclined towards its crest; and this is the critical moment when a large ship resisting or checking the base of the wave, the upper part flows on, breaks on board, and the vessel is said to ship a green sea. A vessel rolls deeper and easier before the wind with a heavy sea following, catching her sometimes under one quarter and occasionally the other; with nothing to counteract this lifting power, a ship thrown over on one side has to recover herself; but if another sea does not again lift her, the rolling quickly diminishes. What is termed the periodic time of a vessel rolling, appears then from actual observation, is the time it takes for succeeding waves to follow on, and tumble the ship from one side to the other.

Watch two or three boys making a boat roll in a river; so long as they go from side to side, the boat rolls—the moment they cease, the boat becomes still again. A ship under sail heels over according to the strength of the wind, more or less as it increases or lessens; the wind dying away she becomes upright; there is no inherent power in a sailing-ship or steamer to go from side to side like a pendulum, unless some external force continually acts on them. An iron light-ship in the Bristol Channel, fitted with rolling chocks 15 in. deep, proved pretty clearly that she rolled with the water, not in it, for in a short time the spaces between the chocks were completely filled up with mussels, that when removed amounted to tons in weight; now, had the vessel have rolled in the water, the dash against the chocks would have prevented the mussels taking up such snug quarters,

If therefore bilge-keels do not prevent rolling, and interfere with the steering of a ship, why continue the use of them? I ask the question, may not the difficulty of steering some of the large iron-clads (having to be fitted with hydraulic or steam-power for the purpose), be caused by their requiring so much more helm, in consequence of the resistance of their bilge-keels? It might be a useful experiment to remove them from the one that steers the worst, and carefully observe if any change took place either in rolling or steering; I cannot fancy she would be in any way a worse ship after their removal, and most certainly an easier one to steer. I am not aware that the question of the value of bilge-keels, or their interfering with the steering of a ship, has been brought before this institution, and I feel that an expression of the opinion of practical men might be very useful, as several of our large iron-clads are fitted with them.

Now that so many merchant steamers are being built eight or nine times the length of their beam, with comparatively small engine power for long voyages, it will be useful for the masters of those vessels to have some ready method of calculating the power absorbed by the rudder at given angles, to compare with the power of engine. A vessel of this class was lost not long since; had her captain known the relative power of his engine and rudder he would probably have kept a better offing, and saved the ship. To first-class steamers with powerful engines it may not be of so much consequence, but still a correct knowledge of speed and rudder-power would be a help—as head to sea, in heavy gales, the rudder has little guiding power; and at an angle supposed needful to get a vessel out of the trough of the sea, might almost nullify the power of the engine. It may be said a seaman knows all these things intuitively; nevertheless the observations of a landsman, without responsibility to distract his attention, may suggest new ideas, and partly with this view I have written this paper.

# WATER CONTAMINATION AND SPECULATIVE CHEMISTRY.

From "The Engineer."

Viewing the indispensability of water as an article of large consumption in our dietary rations, and considering, moreover, that it is an article of diet which, unlike many others, admits no possibility of choice to the inhabitants of a large city such as London, one cannot wonder that so much popular anxiety is shown in respect to its *noxious* impurities. We emphasize *noxious*, because, without such adjective qualification, the word impurity, used in its chemical and obvious sense, would cease to convey to the general public any intelligible meaning. Now, unfortunately, the question, What is a noxious water impurity? has to be begged; and as to the response there exists—not only amongst individuals of the general public, but amongst water analysts themselves—a wide divergence of opinion. The case is one that imposes special difficulty on the analyst, for the reason that he starts from no fixed point or condition having special claim to the designation "normal." If such a thing as absolutely pure water had been presented to us anywhere by nature—if demonstration had been made that such absolutely pure water was better than any variation from that standard for dietetic use—then the chemical analyst, in laying the results of his experiments before the public for purposes of general utility, would have been absolved from many difficulties and causes of error which now beset him. Proceeding from analytical deductions to practical means for ameliorating the condition of a given water supply, he would know at least what to aim at, even though the result achievable might—as it assuredly would—fall short of the aim. He would try, by all expedients in his power, to approach the condition of distilled water—a liquid compound of oxygen and hydrogen wholly, nothing dissolved in it—not even atmospheric air. Now, such a liquid is absolutely foreign to nature. When artificially prepared, and tried for purposes of experiment, it is found to be so prejudicial to health that such water has to be aërated before the stomach can gratefully receive or advantageously appropriate it. Were there a possibility of furnishing London with no water but distilled water, and that in adequate quantity, such water must actually be more or less contaminated before adaptation to the dietetic needs of man. Without aërial impregnation at least, it could not be readily digested, and without the presence of a small amount of mineral matter—by preference, lime carbonate—it would rapidly corrode all lead with which it might come into contact, and thus—lead tanks and pipes being a necessity—would induce universal poisoning.

In consequence, then, of unacquaintance with the best standard of water for dietetic purposes, the reports of water analysts have of late years shown more divergence than might have been expected from professors of a correct science. This divergence is more physiologically speculative than rigidly chemical, attributable not so much to variations of record in regard to things found as in respect to methods of grouping them, and to speculative opinions founded upon them. In cases where the water analyst is a medical man considerable license may be accorded for expressions of belief as to nocuity or innocuity, though even then the analyst would perhaps do well to publish mere records of analysis, leaving independent minds to fix relations and impute physiological qualities to things found, which the analyst himself could hardly do without begetting the impression that he may have conducted the analysis under the influence of bias.

Far be it from our meaning to impute to any analyst of experience and reputation that the influence of any bias would affect his estimation or non-estimation of this or that material. We have already explained that the real difference between non-accordant chemical reports of one and the same water is preferable to variation in mode of grouping things found partly, but still more to collateral inferences and deductive guesses. To give a frequently occurring example, the following may be cited:—A portion of water holding nitrite or nitrate of ammonia—perhaps both—is sent for analysis to two different chemists, one of whom is under the firm conviction that the salts in question can only find their way into water through previous sewage contamination, whilst the second chemist holds the contrary belief, that nitrite and nitrate of ammonia can find their way into water through electrical and atmospheric agencies. Now,

according as the results of analysis may have been set down and commented upon under the influence of this belief or that, the reports may vary in tendency from the point of absolute condemnation of the water for dietetic purposes to the opposite extreme of proclaiming it wholly salubrious. There is nothing prejudical to health in either nitrite or nitrate of ammonia to the possible extent of their existence in any sample of water. The presence of these salts is merely laid hold of as furnishing collateral proof of another and previous condition, the insalubrity of which is fully admitted. We consider it a subject to be regretted that of late years there has been a tendency to prosecute chemical analyses under a system of collateral proof and inference, which if not guarded against threatens to bring uncertainty into what ought to be a certain science. What, too, awakens much regret is the fact that, under the aspect of extreme precision, this prosecution of analysis by collateral proof, or rather inference, not unfrequently gives rise to inevitable and abundant error. Thus we emphatically protest against the use of quantitative color tests on any possible occasion; but perhaps our objection lies in the highest degree against these agents when used as now commonly prevails in water analysis. The time is not so far removed when evidence of the balance—weighing—was alone accepted as worthy of faith in any statement of things found in the progress of analysis. At present, in many sorts of analysis, weighing has become rather the exception than the rule, volumetric estimation having supplanted it. There is nothing to be urged against the cases of volumetric analysis, in which weighing is indirectly involved; as, for example, in comparing a known volume of cloride of sodium solution of known strength with a corresponding volume of solution of nitrate of silver. In that case, and others similar, the operation of weighing, instead of being wholly dispensed with, as at first would seem to be the case, is only thrust a stage back, namely, back to the operation by which the original test solution was made. The class of volumetric, so called *quantitative*, estimations to which we emphatically object, comprehends the professed estimation of various things, not qualitatively but quantitatively, by judging of the precise depth of tint imparted to a fluid on addition of a stated constant quantity of test solution in a glass vessel of assumed constant shape and capacity. We are loth to impugn by name any test which bears the name of a chemist who devised it, but water analysts will easily recognize one test of this description as especially present to our minds. We impeach the accuracy of this sort of miscalled *quantitative* chemistry altogether. Under no circumstances would the application of such a test evolve correct qantitative results; but, perhaps, the strangest cause of objection lies in the pretence of a quantitative accuracy, with which all evidence accruing from tests of this kind is invested. To see the fraction of a grain of ammonia in a gallon of water stated in the fourth or fifth decimal place, as is now often done on the evidence of a much-used color test, is positively absurd, and when on such evidence physiological theories of disease origin are founded, one cannot but marvel at the small amount of testimony on which a theory can find popular acceptance.

The wide divergence of opinion which prevails amongst various analysts as to the nocuity or innocuity of various things present in water, shows at least that room for doubt still exists on many points of this subject. On a former occasion we ventured to propound the question, whether the very prevalent belief in the superiority for potable use, of deep-well water over every other natural water, be a fact so well established as most doctors would have the public believe? If it really be a fact, then, the digestion of man must be amenable to conditions differing from those of all other vertebrate animals. Every groom knows that deep-well water is more prejudicial to a horse than even the water of a muddy stream. Every intelligent herdsman knows the same rule applies to his cattle. If it be a fact, then, it is a curious fact that deep-well water, highly charged, as it mostly is, with mineral substances, should suit the digestive powers of mankind better than the water of running streams. One question more in the spirit of investigation we would like to propound to microscopists and medical authorities. It is, whether since the imagined tracing of cholera distribution to the presence of a specific germ conveyed mostly by water (the demonstration has never been actually made out), the fear of all organic germs has not been overstrained? We would not be understood as denying the connection alleged to subsist between the dissemina-

tion of cholera by a specific germ; on the contrary, the affirmative commends itself strongly to our belief; but in all cases it is well to establish sharp distinctions between things proved and other things strongly suspected. Granting, for purposes of argument, the existence of cholera germs, typhus and typhoid germs, and others many, it does not still therefore follow that chemists and microscopists are justified in considering each and every species of organic germ present in water to be necessarily prejudicial to human health. With equal reason might an indictment be laid against the air we breathe, which, under each and every possible condition of respiration, conveys into our lungs myriads of organic germs. The atmosphere teems with those small forms of life, some prejudicial doubtless, but the majority harmless, nay, according to the belief of certain naturalists, advantageous, the opinion having lately gained ground that certain of these air-borne germs have some important and yet undiscovered function to perform in the economy of animal life.

## LAND SPANS AND ARCHES.

From "The Building News."

The majority of bridges erected over rivers and streams have one or more land spans. By the term "land span," or "land arch," is meant the span or spans nearest to the abutments, under which no water flows, or flows only at certain times. This is the broadest definition of the term, and some discrimination must be used in its application. Let us, for instance, take the case of a bridge of five or six arches or spans, erected over a wide river in a mountainous district. At certain seasons of the year all the spans, with, perhaps, the exception of the centre one, will be dry, and passable for both vehicles and pedestrians. But during the autumn and winter the floods from the upper levels will be so violent as to form a deep and rapid current, extending from one abutment to the other. Although the majority of the spans are, therefore, dry at certain times of the year, they can scarcely be called land spans. But there is another case which bears out more correctly the signification of the word. It is that of a tidal river, which is not dependent upon periodical floods or heavy storms for the varying level of its waters, the height of which is regulated by the rise and fall of the tide. Again, there is a third case, which may be considered as the true exposition of the technical phrase. This occurs when the arch or span nearest the abutment is built designedly for the purpose of affording a passage underneath for ordinary traffic. A common example is to be seen in the bridges over large canals and navigable rivers, upon which barges are in the habit of plying. To allow a passage for the towing path, a small arch is generally turned at one or both sides, which is in the strictest sense a land arch. Independently of all these considerations, a land arch is frequently attached to a super-aqueous bridge for no other reason than to avoid placing the abutment too near the water. When the foundations are bad, or of a treacherous, unreliable character, it is preferable to found the abutments some short distance inland, which consequently leaves the span intervening between them and the first piers on either side nearly dry. There is still one more case to be noticed, which embraces all those examples in which originally the water way extended from one abutment to the other, but from alterations in the course of the river, either naturally or artificially, one or other of the extreme spans have become dry. This last consideration brings us to the more immediate subject of our article.

It is said that the present Thames Embankment, upon the Middlesex side of the river, was projected and discussed fully thirty years ago, but that owing to that procrastination which ever attends the carrying out of public works, it was shelved and put off from time to time, until its execution devolved upon the men of our own day. From the manner in which some of the modern bridges over the Thames have been built it is evident that but very little attention was bestowed upon the probability of the Embankment being constructed. Waterloo Bridge, being anterior to even the proposition of the Embankment, may be omitted in the category; but the manner in which the wall joins in with Blackfriars Bridge is certainly neither pleasing to the

eye nor in accordance with the general run of the river. Standing on the bridge at a point nearly vertically over the first pier from the Middlesex end, and ranging the line of the Embankment wall, its direction, if prolonged, would nearly catch the pier, and by a gentle curve could have been brought into it, thus converting the arch springing from the northern abutment into a land arch. As it is, the wall is brought by a curve in the reverse direction to meet the abutment, and forms a re-entering angle, terminating in a complete *cul-de-sac*, where deposits will rapidly accumulate. A glance is sufficient to demonstrate to the merest amateur that the line of the wall should have been kept back or the northern abutment of the bridge pushed forward. The true mean would have been obtained by making a slight alteration in the present position and direction of both. It may be urged that in taking this view of the matter we have only had regard to the up-stream side of the river, and that the position of the abutment of the bridge of the London, Chatham and Dover Railway, in some measure regulated that of the Blackfriars Bridge and the Embankment wall. That there is some justice and force in this remark we do not pretend to deny, but the plea is not sufficient to excuse the sharp fork that is formed between the northern abutment of the bridge in question and the wall.

Returning to the conversion of wet spans into dry ones, the railway bridge at Charing-cross furnishes an excellent instance in point. There are now three dry, or land, arches on the Middlesex shore. One of them certainly cannot be called a *dry* span, as will be presently explained. Under one of these spans the main road of the Embankment passes. The next is appropriated by a portion of the roof of the Metropolitan Railway Station, and constitutes one of the most hideous sights along the whole riparian route from Westminster to Blackfriars; and the third and last is carried over the back road connecting the main thoroughfare and that leading from Whitehall with Villiers street, the upper end of which opens into the Strand. While alluding to this street, it may be mentioned, *apropos* to the matter, that unless a sufficient number of thoroughfares connecting the Strand and Fleet street with the Embankment are opened up, the greater part of the value the latter work is supposed to confer upon the public will be lost. The continuation of Villiers street should have been laid out to the left, looking towards the river, and not taken round under the Charing-cross Bridge, thus obliging a vehicle coming from that part of the Strand to the river to pass twice under the same bridge and circumnavigate the Underground Railway Station. The leakage of railway bridges erected over metropolitan streets is notorious, and the companies have been compelled to take means for preventing it. The usual method is to sheet with zinc those portions of the soffit which are over the footpaths, or to put up a kind of zinc cover or screen, while proper gutters and down-pipes are supplied for carrying off the water as it accumulates. Something of this sort ought to be done with the soffit of the land or fan-shaped span of the Charing-cross railway bridge, as its present state is simply disgraceful. It not only leaks, but there is a regular down-pour of water at various points upon the pathways and road beneath. It would appear as if the methods for accomplishing the drainage of the superstructure, when there was water underneath the span instead of a road, had been left unaltered. As yet, it is true that there is no thoroughfare from the Strand to the Embankment *via* Villiers street, but that is no excuse for allowing the state of affairs to continue. The way is open to pedestrians; they ought not to be compelled to put up their umbrellas in passing under a bridge. Neither can the plea of expense to the Company be accepted as exonerating them from their responsibility, for it was perfectly well known at the time the bridge was built that before long the river would be diverted from some of the spans, and that they would ultimately be over roads and metropolitan thoroughfares; but with the actual party upon whom it may devolve, legally or equitably, to make the road passable, we have nothing to do. In the interest of the public, whenever new routes and streets are carried under bridges which may formerly have spanned a waterway, it is sombody's duty to see that the soffits are water-tight, and that the drainage is discharged into the proper receptacles for it, and not upon the persons of the unfortunate wayfarers below.

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The New Zealand Government has agreed with Messrs. Brogden and Sons for the construction of eight miles of railway from Wellington to Pitone.

# COMPRESSED AIR ENGINES.

From "Engineering."

The plan of working tramway cars or other vehicles by turning to account the power stored up in a supply of compressed air, is one which has been frequently proposed, and which has in several instances been carried out in practice with results in some cases satisfactory, and in others of a decidedly opposite kind. In America, in particular, this system of propulsion has attracted much attention, and we, from time to time, receive from the United States reports of the more or less successful trials of various modes of carrying out the system in practice. It unfortunately happens, however, that the data available concerning these trials are generally of the vaguest possible kind. They inform us, perhaps, that a car fitted up with a compressed air engine made such and such trip in such and such a time, and that the performance was successful, or that it failed in some way or other; but we are doubtful if any really complete series of experiments has ever been made with one of these engines, or at all events we are unaware of a report of any such experiments having been published. By a complete series of experiments on a compressed air engine we mean a trial, or series of trials, of the engine on the line of which the gradients are known, and with a load also known, there being taken during the run or runs, a continuous series of indicator diagrams from the cylinders, and contemporaneous observations of the temperatures and pressures of the air in the reservoir, and in the pipe leading to the cylinder, besides a record of the temperature of the air as it is discharged from the cylinder into the atmosphere. The barometric pressure and the temperature of the external air, and the amount of moisture present should also be noted, while a record might also be kept of the temperatures of the external surfaces of the reservoir, of the pipes communicating with the cylinders, and of the cylinders themselves.

From such a series of observations as that to which we have alluded, some valuable data might be deduced bearing upon the construction of pneumatic locomotives, and we believe that a great deal of the time and money at present spent in so-called practical experiments might be saved. It would be possible, for example, to deduce from such observations information respecting the rates at which the air during expansion took up heat from objects with which it was in contact, and to determine the extent to which the heat converted into work was replaced by other heat absorbed by external sources. These data being obtained, it would become possible to determine approximately the best proportions between the initial and working pressures of the air used (for in most cases the pressure of the air is materially reduced on its way from the reservoir to the cylinders), the best cylinder capacity to employ for a given amount of work to be performed, and the best place to make up, or try to make up, the loss of heat due to work done. The determination of these points, even approximately, would be of immense service to those who are endeavoring to bring pneumatic propulsion into use, and instead of working in the dark, as at present most—if not all—of them appear to be doing, we should earnestly recommend them to carry out such trials as those of which we have spoken. If they were to do so we feel certain that the cause in the progress of which they are interested would be most materially benefited.

From the time that the system of working engines by compressed air was first proposed, down to the present, on of the most annoying practical difficulties with which the advocates of the system have had to struggle, has been the excessive refrigeration caused by the expansion of the air, and the consequent freezing of the moisture contained in it; this freezing resulting in the blocking up of the pipes and passages with ice. To avoid this trouble, it has been proposed to heat the air on its way to the cylinders by passing it through pipes enclosed in a stove or furnace, or to envelop the cylinders in jackets through which the products of combustion of a stove might be made to circulate; while, in the case of the submarine boats built at St. Petersburgh some time ago for the Russian Government, and which are driven by engines worked by compressed air, the plan was resorted to of connecting the engines with the reservoirs by a number of pipes, and shutting off the current of air through any of those pipes in which ice might accumulate, so that the

latter might be thawed by the absorption of heat from external sources. In some cases upwards of thirty pipes were used to connect the engine with the reservoir of air. This plan of employing a number of connecting-pipes no doubt meets a portion of the difficulty; but it is a plan requiring more attention than it is desirable should have to be bestowed on the working of engines fitted to tramway cars, while the proposals to heat the air on its way to the cylinders, by passing it through tubes exposed to the fire of a stove or furnace, or to heat the cylinders by means of jackets traversed by products of combustion, are also open to objection on practical grounds. Amongst other things there is, if either of these latter plans be resorted to, always a risk of giving to the air, prior to its admission, or to the cylinder itself, such a temperature as to destroy the lubricating material employed, and thus cause "cutting" to take place.

Having objected to the principal plans proposed for obviating the difficulties resulting from the refrigeration of the air during expansion, it is only fair that we should point out what we believe to be a preferable mode of getting over these difficulties. This mode consists simply in the employment of a hot-water jacket for both the cylinders and reservoir, and in the adoption of a sufficiently slow piston speed. The water jacket may consist simply of a tank well lagged externally, and sufficiently large to contain the air reservoir, the connecting pipes, and the cylinders; or, if preferred, the reservoir and the cylinders may be enclosed in independent jackets or tanks, it being merely necessary to take care that each jacket contains a sufficient supply of hot water to furnish the heat required of it during the run. It may, at first thought, be supposed that the quantity of water required to supply this heat would be so great as to render the plan proposed an impracticable one. So far from this being the case, however, the quantity required is remarkably small, as we shall show on a future occasion, when we treat of the question in greater detail; and we may remark here, that for running a 6-ton car for three miles over a fair ordinary road, the quantity of hot water required for the jackets would be but about 20 gallons only, it being supposed that this quantity is renewed by a fresh supply at a temperature of 200 deg., or reheated, say, by blowing steam into it at the commencement of each trip. In some cases where a stove is employed to warm the car, the heat from this stove could be turned to account for maintaining the temperature of the jacket water.

We have mentioned that, in addition to using hot-water jackets, it appears to us desirable that a slow piston speed should be adopted for compressed air engines, and we may explain briefly why we hold this opinion, an opinion which may, perhaps, be opposed to the experience of some who have worked such engines without jacketed cylinders. Let us, for instance, consider the case of an engine in which the air, stored up at a high pressure in a main reservoir, is led thence, through a reducing valve, to an intermediate receiver, in which it is maintained at a constant pressure, while from this receiver it passes to the cylinder, and is cut off in the latter at, say, one-third the stroke. In such an arrangement the work expended in the intermediate receiver in supplying air to the cylinder is balanced by that developed by the entrance of the air from the main reservoir, and under these circumstances the intermediate receiver is exposed to neither a loss nor gain of heat, so long as the air flowing into it from the main reservoir is maintained at a constant temperature. The work done during the first third of each stroke prior to the valve closing the admission port, is really done by the expansion of the air in the main reservoir, and it is to that reservoir, consequently, that the heat must be supplied if the air flowing to the cylinder is to be maintained at a constant temperature. With a hot-water jacket there need be no difficulty in adopting such a form of main reservoir as will enable this required amount of heat to be communicated to the contained air with certainty. After the point of cut-off is passed, however, the work done in the cylinder during each stroke is performed by the expansion of the air contained in the cylinder, and this expansion is, of course, accompanied by a refrigerating effect. To prevent the temperature of the air in the cylinder falling so low during this expansion, it is desirable to supply heat from external sources while that expansion is taking place. But air takes up heat but slowly from the surfaces with which it is in contact, and hence, that the heating to which we have referred may be successfully performed, it is necessary either to envelop the cylinder in a jacket of which the con-

tents are kept at a high temperature, or to employ such a slow piston speed that time is given for the absorption of heat from a jacket of which the contents are but moderately heated. For several practical reasons we prefer the latter alternative, and hence it is that we advocate slow piston speeds for compressed air engines. What the best piston speed may be it is impossible at present to say, as data for arguing the question properly are wanting; but we consider that there is evidence available to show that this speed is much lower than has hitherto been generally adopted for such engines, and we believe that the matter is one which has not hitherto received the attention which its importance deserves. Air, it must be remembered, possesses very different qualities to steam, and the arguments in favor of high-piston speeds for steam engines certainly do not apply to motors worked by compressed air. We have now directed attention to some of the leading points connected with the system of working engines by compressed air; but we have very far from exhausted the subject. There are said to be more ways of killing a dog than hanging him, and it is equally true that there are more ways of getting rid of the trouble arising from frozen moisture in the class of engines of which we have been speaking than that of jacketing the reservoir and cylinders. A consideration of these methods, however, we must leave for a future article, when we shall also have something to say of the system from a quantitative point of view; or, in other words, shall speak of the amount of compressed air which it is necessary to carry to perform a given amount of work, and shall probably treat of the efficiency of the system as a whole.

## ORIGIN AND GROWTH OF ROMANESQUE ARCHITECTURE.

By EDWARD A. FREEMAN.

From "The Building News."

The only sound classification of styles of architecture is that which arranges them according to their leading principles of construction. Of such principles, as far as we know at present, there are only three; more accurately speaking, there are only two, one of which again falls into two great subdivisions. The two great systems of construction are the Entablature and the Arch, and the arch again may be either round or pointed. We thus get three distinct forms of construction, the Entablature, the Round Arch, and the Pointed Arch. And each of these principles of construction has been, in its own time and place, the animating principle of a style of architecture. That is to say, there have been times and places in which each of the three has not only been the prevalent form of construction, but has been accompanied by an harmonious and consistent system of decoration. Each of the three constructive principles may be looked on as the expression of an æsthetical principle. In the case of two out of the three this is generally acknowledged. It is universally felt that the architecture of the entablature is the expression of horizontal extension, that the architecture of the pointed arch is the expression of vertical extension. It is generally acknowledged that the perfection of the horizontal idea is to be found in the highest form of the architecture of the entablature—that is, in the architecture of old Greece. It is generally acknowledged that the perfection of the vertical idea is to be found in the highest form of the architecture of the pointed arch, that is in the Gothic architecture of mediæval Europe. It is not so generally acknowledged that the intermediate form of construction, the round arch, has also its leading æsthetical idea. It is not so generally acknowledged that there have been times and places in which the round arch also has produced a style, not perhaps approaching so nearly to ideal perfection as either of the other styles, but still coming near enough to it to be set alongside the other two as an independent and equal form of art.

Yet, if we admit the entablature, the round arch, and the pointed arch to be the three chief, and seemingly the three only possible forms of architectural construction, it seems necessarily to follow that the round-arched construction must have its leading æsthetical idea no less than the other two, and that it must be capable, no less than the other two, of an ideal perfection. Whether it has ever actually reached its perfection or not, whether it has ever come

so near to it as the other two have, is a question which is not now to the point. It will not do to say that there is a perfection of the arched style, but that its perfection must be looked for in the architecture of the pointed arch, and that the architecture of the round arch is an imperfect form. The answer is plain; the round arch is constructively as good a form of construction as either the entablature or the pointed arch. As a mode of building, it stands on a perfect level with them. Now, if we admit that all good and honest architecture consists in finding appropriate forms of decoration for good and honest forms of construction, it would seem to follow that every good and honest form of construction must be capable of finding some appropriate form of decoration, and of thereby reaching an ideal perfection. It seems, then, to follow that the architecture of the round arch has a right to be looked on as an independent form of art on a perfect level with the architecture of the entablature and the architecture of the pointed arch. Of course, it does not follow that it has ever been actually carried so near to ideal perfection as either of the other styles. It is enough if we allow that it has, like them, its leading idea, and that it is capable of an ideal perfection, whether it has ever actually reached it or not.

Some of the causes of the general unwillingness to admit the claims of the architecture of the round arch to an equal place alongside of the other two great forms, are obvious enough. First of all, I am free to admit that the architecture of the round arch never has, as a matter of fact, been carried so near to perfection as both the other two forms have. There is no round-arched building so absolutely satisfactory as a work of art as either the best Grecian or the best Gothic buildings. In comparing Romanesque and Gothic buildings, a much greater share of the charm of the Romanesque building belongs to its age and its historical associations, a much less share to its actual merit as a work of art. I know not how others may feel, but to my own mind this is proved by the following test. A modern Gothic building, if it be really as good as an ancient one, is as satisfactory as an ancient one. But a modern Romanesque building is, to my mind at least, simply grotesque. The more closely it reproduces an ancient building the more grotesque it becomes. This, I think, proves that, in the case of the Gothic building, we do, in the strictest sense, admire a work of art, while a great part of the charm of the Romanesque building is derived from other sources. But, if round-arched architecture has never been actually carried so near to perfection as the other two styles, that fact in no way disproves its abstract capacity of reaching an equal relative perfection. Secondly, though I believe the round-arched style to have a leading idea equally with the other styles, and to have equally with them an appropriate form of decoration, yet neither the leading idea nor the appropriate form of decoration is quite so obvious in the case of the round-arched style as it is in the case of the other two. There is something negative about all the characteristics of round-arched architecture. While the leading idea of the architecture of the entablature is that of horizontal extension, while the leading idea of the architecture of the pointed arch is that of vertical extension, I take the leading idea of the round-arched style to be that of no extension either way, but of simple rest and immobility. The round-arched form again has another peculiarity. No other can so well dispense with ornament. Either a Grecian or a Gothic building would be wholly intolerable, if it were so utterly void of ornament as many Romanesque buildings are which are perfectly satisfactory in their own way. Indeed, we may safely say that, the larger a Romanesque building is, the plainer it may be, perhaps ought to be. A small chapel in that style is commonly much richer than a great minster. What, too, is the nature of Romanesque ornament, when we get any? It is again something of a negative kind. The Greek mouldings are of a kind which serve to strengthen the horizontal lines supplied by the construction of the building. The Gothic mouldings are of a kind which serve to strengthen the vertical lines supplied by the construction of the building. In Romanesque neither of these forms seems appropriate. A round arch moulded after either the Grecian or the Gothic fashion is never satisfactory. Either the horizontal or the vertical idea is suggested, and each of them is inconsistent with the spirit of a style whose leading idea is pure rest and immobility. Moulding, indeed, in the strictest sense of the word, moulding which affects the section, is really out of place in a Romanesque building. The true Romanesque ideal leaves the orders of the arch in their natural square section, and seeks enrich-

ment by ornament on the surface, whether by colored ornament, as in Italy, or by what we may call surface-moulding, as in our own Norman. At most it attaches a heavy roll —a continuation of the jamb-shaft—to the square section, instead of carving the square section itself away, as in the Gothic system of mouldings. In all this we see the negative character of the style. It has a leading idea; it has an appropriate form of ornament; both are capable of definition; but both are perhaps most easily understood by describing them as something which is neither Grecian nor Gothic. Again in our Northern Romanesque, though there is a stateliness and majesty above all other styles, there is seldom anything to be called real beauty of detail, such as we find in Grecian on the one side and in Gothic on the other. The truth is that the time when the round-arched style came nearest to perfection in the general design of its buildings was a time when, in northern countries at least, the decorative arts were at a very low ebb. An English sculptured capital of the 13th century is, in its way, as beautiful as anything in Greek art. But when a capital of the 11th or the first half of the 12th century anywhere north of the Alps attempts sculpture, animal or vegetable, the effect is simply grotesque. We may apply the test which I before gave. A modern reproduction either of a Corinthian or of an Early Gothic capital may be fully as pleasing to the eye as the original. But a modern imitation of an enriched Norman or Lombard capital, with its rude volutes and its strangely disproportioned men and beasts, is not pleasing, but ridiculous. It has not the charm of antiquity and historical association which belongs to the original, and it has nothing to put in its place.

This last difficulty, strongly as it may be felt in most Northern and in some Italian Romanesque, would prove nothing at Pisa or Lucca. But all that I have been saying as to the negative character of Romanesque architecture, and as to the lack of beauty in its detail, would of itself go far to account for the unwillingness so commonly felt to see in the architecture of the round arch an independent style, ranking alongside of the architecture of the entablature and that of the pointed arch. But I think that we have not yet got to the root of the matter. To admit the round-arched style as an independent form of equal rank with the other two, involves giving up a whole train of notions about ancient and modern, Classical, and the like. If we are to admit the claims of the round-arched style as I have put them, we must altogether wipe out the hard and fast line between ancient and modern. We must admit the continuous existence of a style whose earlier examples were the work of "Classical" Romans, while its latter examples were the work of Barbarians, Goths, and the like. It would be hard to make many people believe that a really wider line ought to be drawn between two forms of Mediæval work than between one form of Mediæval work and one form of Classical. It would be harder still to make them believe that one form of Classical architecture ought to be looked on as a mere imperfect transition to a style which was brought nearer to perfection at the hands of Mediæval barbarians. To those who take a wider view of general history there is no difficulty in all this. Sweep away the distinction of "ancient," and "modern"—cease to look on things "Classical" as something all by themselves, hedged in from everything belonging to other times and nations—learn to look on history as a whole, and the history of Greece or of Rome simply as a part of that whole—and there will no longer seem anything strange or incongruous in holding that, in architecture, in language, or in anything else, the function of the first century on either side of our æra was simply to pave the way for the eleventh or twelfth century after it. Once grasp the true life and spirit of the long Imperial history, and there will seem nothing wonderful in fixing on the third century, in purely Classical eyes a time of decay and degradation,, as a time which, alike in religion, in law, and in art, stands out as one of the great creative ages of the world.

The essence of good architecture of any kind is, that its constructive system should be put boldly forward, that its decorative system should be such as in no way conceals or masks the construction, but makes the constructive features themselves ornamental. Both in Grecian and in Gothic architecture this rule is thoroughly and consistently carried out. In a Grecian building the entablature is the main feature of the construction, and it proclaims itself as such. In a Gothic building the pointed arch is the main feature of the construction, and it proclaims itself as such. In neither case is there any attempt at concealment or

disguise of any kind. But how stands the case with Classical Roman architecture? Here we have a style in which the main feature of the construction is not made the main feature of the decoration. Here we have a style in which the great constructive features seem, as it were, ashamed of themselves, where they try to hide themselves behind a mask borrowed from a different system of construction. The architecture of Classical Rome is, like the literature of Classical Rome, imitative. Italy, the land to which the world practically owes the great discovery of the arched construction, may very likely have had a native architecture, as well as a native literature, in the days of the Kings and the early Consuls. But the architecture of Classical Rome was a mere imitation of that of Greece. It was indeed but an imperfect imitation. The Roman architects were not so besotted as to cast away their own great invention of the arch, and to fall back on the less flexible, less diversified, constructive system of the Greek entablature. But just as they spread a varnish of Greek forms, Greek metres, and what not, over their native Italian literature, so, in like sort, they spread a varnish of Greek decoration over their native Italian construction. Buildings whose real construction was that of piers and arches, were masked with a decorative imitation of the columns and entablature of a Greek portico. But as it was in other things, so it was also in architecture. The true Roman spirit was masked only, and not destroyed, by the fashion of Greek imitation. As that spirit shows itself in the satirists, the historians, and even here and there in the poets themselves, as it stands out more clearly still in the mighty fabric of the Roman law, so there are classes of Roman building in which the national arched construction stands out, masked but feebly, or not at all, by the varnish of Greek decoration. In an aqueduct or an amphiteathre, Greek features, columns and their entablatures, are either absent altogether or are something so secondary as to have but little share in the general effect. In buildings of this kind, the round arch, the main constructive feature, does really stand out as the feature which gives the building its main architectural character. And, as Mr Petit remarked long ago, the step from buildings of this kind to some of the plainer forms of the later Romanesque is very slight indeed. Some of the great German churches, such, for instance, as the three great Rhenish minsters of Mainz, Worms, and Speier, where the interior elevations consist of square piers supporting perfectly unadorned round arches, have surely a great deal in common with a Roman aqueduct. In both we see the round-arched construction standing boldly out in its most undisguised form. And buildings of this kind, whether aqueducts, amphitheatres, or churches, which rely almost wholly on their unadorned constructive elements, may undoubtedly be grand and striking in the highest degree. Still, a style of architecture would be narrowly limited in its resources if it were forever confined to such elements as these. The massive, unadorned, square pier was suited for many purposes; but there were also many purposes which asked for something more graceful, something which better offered itself for enrichment. There was one feature of the Greek constructive system which the Roman architect could do something more than blindly imitate. There was one feature which he could really adopt, for which he could find a place in his own system as appropriate as that which it had held in the system to which it belonged by birth. The Grecian column was freely employed by the Roman architects, but for a long time, in truth during the whole of the purely Classical period, it was used only in a feeble, hesitating, and inconsistent way. Roman architects built porticoes and colonnades after purely Grecian models, without bringing in any feature of the national constructive system at all. Or columns and entablatures after the Grecian model were attached as a mere decorative mask to buildings really built according to the national mode of construction. At last, in days which we are taught to look upon as days of decline, in days which are looked upon as days of degradation both for literature and for art, the great step was taken which was to give Roman architecture an harmonious and consistent form, the step which was to make its chief decorative feature become also the chief feature of its construction. In the Greek system the column had boldly and honestly supported the entablature. In the Roman system of construction, the round arch answered to the entablature. What, then, was needed to make the column a real feature in the Roman system was to make it discharge in the Roman construction a duty strictly analogous

to that which it had discharged in the Greek construction. In the Greek system the entablature had rested on the capitals of the columns; what was now needed was to make the round arch rest on the capitals of the columns also. This simple change at once gave Roman architecture a form both consistent in construction and graceful in decoration. Next to the introduction of the arch itself, no architectural revolution has been so great and so lasting in its results. The man who first boldly set his arch to rest on the capitals of his columns made a change which led the way to all future developments of arched architecture, round and pointed alike.

The first building, as far as we know, in which this great change was made was the palace of Diocletian at Spalato. No time, no place, no author, could be more fitting for such a great architectural revolution. The change was not made in the local Rome, but on the other side of the Hadriatic, in a land which the Romans of an earlier time had looked on as a distant and barbarous province. But in those days the local Rome had ceased to be the only Rome. Rome was now wherever the Roman law and the Roman language had spread themselves, wherever men submitted to the rule of the Roman Cæsar. And no corner of the Empire was then more truly Roman than the Dalmatian land which sent forth that long succession of wise and valiant Emperors, Roman in every nobler sense of the word, though the local Rome was neither their birthplace nor their dwelling-place. And it was well that the greatest of them all, the founder of the Empire in its later form, should also be the man at whose bidding the first consistent Roman building rose. The keen eye of Diocletian had at last seen that the Roman Commonwealth was at an end; he grasped the fact that the Empire was a monarchy, and grasping the fact, he had not shrunk from putting it prominently forward before the eyes of men. The Illyrian peasant, in the days of his power, had been the first to deck himself with the outward pomp of royalty, when so to do was simply to give an outward expression to what for many generations had been the greatest of practical facts. The same man, in the days of his voluntary retirement, carried out a change in Roman art exactly analogous to the change which he had already carried out in the Roman polity. Alike in polity and in art, he swept away traditions which had become cumbrous and useless, and let things stand forth as they really were. Alike in recasting the constitution of his Empire and in designing the hall of his palace, Diocletian made the real construction of the fabric stand forth undisguisedly before the eyes of men. Alike in his political and in his architectural creation, he put the crown to the work towards which his predecessors had been feeling their way for three hundred years.

The palace of Spalato I have never seen with my own eyes, but the views of it given by Sir Gardner Wilkinson are quite enough to set its main features clearly before us. The new invention is not, indeed, consistently carried out throughout the whole building; that would have been too much to look for from any architect of any age or country. But it is applied to the long colonnades of the great hall, and noble ranges they are. A consistent round-arched building has at last been called into being, a building of a less massive and a more ornamental type than the aqueduct, or even than the amphitheatre. As the first consistent arched interior, the hall of Diocletian's palace contains in it the germs of all later architecture; the germs not only of Ravenna and Pisa, but of Caen and Durham; not only of Caen and Durham, but of Westminster and Amiens. As such, there is no more memorable building upon earth. But it is in no way wonderful that the great improvement which it offered was not at once universally accepted. Every architectural development has to go through a stage of transition, a stage when the new principle and the old are striving for the mastery, and when the two are mingled together in various degrees and proportions. The architect of Spalato showed that columns could be used as the immediate supports of arches; he did not at once persuade the whole world to use columns as the immediate supports of arches. Men had been so long used to look upon the entablature as the right thing to rest upon the capitals of the columns, that they could not all at once bring themselves to let the arch come straight down upon the capital itself. It seemed as if something must be done, as if some change must be made, to adapt the capital to its new duties. Something must be thrust in between the capital and the arch; some fragment, as it were, of the entablature, must come between the abacus of the capital and the impost of

the arch. Or perhaps the abacus itself must be enlarged into something like a piece of entablature, or the whole capital must be drawn out to an unusual size and height, in order to seem more worthy of its new prominence, and be able to bear the weight that was laid upon it. For it is manifest, and it is one of the great advantages of the arched construction, that the columns, or other supports of a range of arches, may be placed at much greater distances from each other than the columns of a colonnade supporting an entablature. It follows that each column and its capital assumes in the arched building a greater importance; it has, so to speak, a more distinct separate existence than belongs to the columns of a colonnade. In the later Roman architecture we therefore find all kinds of shifts to avoid that immediate juxtaposition of the arch with capitals of the hitherto accustomed forms on which the architect of Spalato had already ventured. In the basilicas of Ravenna I do not think that there is a single case where the arch comes down immediately upon an Ionic or Corinthian capital.

Those wonderful works of Western Emperors, of Gothic Kings, and of Eastern Exarchs, were reared out of the spoils of earlier buildings. Columns and capitals were brought from various quarters; their proportions did not always exactly tally with one another; a column did not always agree with the column which stood next to it, or with the capital which its own shafts supported. But, among all the shifts to which the architects of these churches were driven in order to keep something like order among the columns which were thus strangely brought together, in every case, whatever may be the form of the capital, a member is thrust in between the capital itself and the arch. For such a member there is no real need, either constructive or decorative; it simply shows how men clave to the idea that the proper use of a column and its capital was to support something like the horizontal line of the entablature. The local use of Ravenna preferred the employment of capitals of the received Classical shapes with this needless member interposed—a member which wants a name, and to which that of the *stilt* has sometimes been given.*

* It is worth noticing that something very like the Ravennese stilt is to be found in the ancient Egyptian architecture in the form of a member, the *de*, interposed between the capital and the entablature. In some forms of Saracenic architecture this stilt becomes a most important feature.

At Constantinople, on the other hand—I speak here not from personal knowledge, but from the Chevalier Fossati's splendid drawings of S. Sophia—though the stilt is not unknown, yet the tendency seems rather to have been towards devising new forms of the capital itself. Some of them, with a different proportion, still keep something like the general idea of a Classical capital, while others, especially the well-known Byzantine basket capital, altogether depart from Classical models. At Ravenna no difference can be discerned between the works of the Roman Placidia and those of the Gothic Theodoric. The wise barbarian who preserved for the conquered Romans their laws, their language, and their buildings, followed their models also in his own original works. But with the recovery of Italy under Justinian new forms came in. In the Church of St. Vital, begun during the Gothic dominion but not finished till after the conquest by Belisarius, the new Byzantine forms of capital are seen. But the local custom did not wholly die out, and the stilt appears in S. Vital also, often taking the form of what we must call a double capital, one being placed over the other. The Byzantine forms, in their later development, are found also among the vast stores of capitals, brought and copied from all possible quarters, which are to be seen in the portico and the galleries of S. Mark's at Venice. But for true columnar arcades, like those of Ravenna, we must leap over several centuries, till we come to the works of the 11th and 12th centuries at Pisa, Lucca, Murano, and Torcello. Here, with the changes of detail which are natural after a space of 800 years, we come back to the same state of things which we saw at Spalato. The arch again rests immediately on the capital of the column, and the columns and their capitals are either Classical remains used up again, or else they are as nearly imitated from Classical models as the art of those ages would allow.

It certainly seems to me that, in these great Italian churches, we have before us a distinct round-arched style, an independent form of architecture worthy to rank side by side either with the architecture of the entablature or with the architecture of the pointed arch. One of the three great forms of construction, a form constructively as good as either of the other two, is here provided with a good and consistent decorative system. It is hard to see what more is want-

ed. It is hardly possible to conceive any architectural forms more perfect and stately than the arcades of the nave of Pisa. The decorative forms are consistent and elegant; in some, indeed, of the later buildings of the style, especially at Lucca, they put on an almost extravagant richness of detail, but yet without departing from the purity of the round-arched ideal. But if we admit that the columnar form of the Italian Romanesque is a pure and genuine style, that it is a legitimate decorative carrying out of one of the great types of architectural construction, it follows that the architecture of Classical Rome must be looked on as something imperfect and transitional. The Romanesque of Pisa and Lucca is the Classical Roman set free from the incongruous elements which clung about it, set free from all traces of the days when Roman architecture was a mere imitation of Grecian form. The one Grecian feature which could be really adapted to the Roman principle of construction has been adopted and naturalized, and it has been proved to be capable of doing as good service in the new system as it did in the old. If here and there traces of another system of decoration may be found hanging about the buildings of this style, they are in positions so unimportant as to be of little consequence in the general effect. They in no way interfere with the claim of the columnar Romanesque to be looked on as a pure and independent style, as the consistent carrying out of an architectural conception which the Classical Roman attempted only very imperfectly. Paradoxical, then, as the position may sound, I think that I have made out my case, and that the Classical Roman is essentially an imperfect style, a mere transition to the more perfect Romanesque.

## NOTES ON SEWAGE.

From "Engineering."

Although much has been said and written on the sewage question, by public officials, and private individuals, it is somewhat remarkable that in no instance, so far as we are aware, has any chemical analysis been published of the sewage of any town in the United Kingdom, carried on for a longer period than about two days consecutively. It is evidently impossible, on such limited premises, that anything like reliable data could be arrived at, on which to form definite conclusions. Despite these defects, however, royal commissioners on the one hand, and public companies on the other, have set forth a variety of schemes, all proving to their satisfaction the easy solution of the question, although such solution is as far as ever from being arrived at. But to this it may be added that there is scarcely a town in the United Kingdom—if indeed there be one at all—which is now dealing with the whole of its sewage in a manner efficiently carrying out all of the conditions required by sanitary considerations, independently of those of profit or loss.

In the absence of such information as that to which we have referred above, the following notes on the varying and average quality and quantity of sewage are offered to those interested in the important question of its utilization. It is hoped that, as the observations and analyses have been conducted night and day, consecutively for two years, in places showing every possible extreme of condition, in a locality entirely free from all manufacturing operations, and in two of the largest manufacturing towns of the kingdom, they may put the sewage question in a very different light to that in which it has been hitherto placed. The chief localities were Leamington, a seat of fashion and high living; with Birmingham and Leeds, as having an entirely opposite social character. On certain occasions, upwards of two hundred experiments have been tried in the twenty-four hours, by the writer and his assistants in the laboratory; and on several occasions he has continued the observations for a period of eighty hours, personally, without intermission.

The following results accrued, and were substantiated by daily, weekly, and monthly reports.

In any town, free from the abnormal circumstances of manufactures, the sewage, *apart from rainfall*, presents constant features. That of Sunday is invariably the weakest in all respects. Towards mid-day on Monday it increases in strength, so far as matters in solution are concerned; arriv-

ing at a maximum at about 11 to 1 o'clock on the Tuesday of each week. It thus remains pretty constant until six o'clock on Saturday evening, when its strength began to abate, over Sunday, as above mentioned.

"Washing days" are especially notable. Tuesdays and Wednesdays present a large amount of fatty matter, causing soapy bubbles on the sewage, and the presence of much alkali (soda chiefly). This fact, which is indubitable, presents great difficulties to all the chemical methods that have been proposed to utilize sewage, as all the chemical conditions are affected. This is especially noticeable when either the A. B. C. (Native Guano) or Dr. Anderson's process is employed. In each an acid, sulphate of alumina, is used. The excess of alkali is attacked by the sulphuric acid in that salt, while the stearine of the soap is set free, as a fatty matter floating on the surface of the effluent water, but blackened by the suspended filth in the sewage. The sewage of Leeds shows these results chiefly on Wednesdays and Thursdays, those being the "clothes" and "house washing-days" in that city. Birmingham shows some singular peculiarities which will be subsequently noticed.

In Leeds, especially, the circumstances of manufactures greatly interfere with daily results, apart from washing-days, which are so definitely marked. On certain days, but notably Friday and Saturday, and less frequently on Tuesday, the dye-becks, or vats, are emptied, and consequently the sewage becomes either brown or black according to the proportions of various dyestuffs thrown into it. Added to this, in its course to Knostrop, where it enters the river Aire, a large percolation of a solution of sulphate of iron, from the adjacent soil, interferes chemically with the character of the sewage, not only in regard to its external appearance, but also in respect to its chemical nature, much of the animal organic substances being precipitated insoluble. At Birmingham this may be specially noted at the sewage works near Saltley, at present carried on by the corporation. At about 11 to 12 in the forenoon the "pickle" containing sulphuric acid and iron, is sent into the sewage, as a waste from cleaning metallic articles incident to the manufactures of the town. Suddenly the brownish black appearance of the sewage is changed to an orange red. This is owing to the alkali of the sewage decomposing the sulphate of iron, setting free the latter as a hydrated oxide, which, coming into contact with the oxygen of the air, produces the sesquioxide of iron—hence the red appearance just referred to.

As a rule, sulphuretted hydrogen is *not present in free running sewage*, although the popular, and even scientific opinion is exactly the reverse. It was never detected, night or day, during fifteen months at Leamington except on two occasions, namely, at about 2 A. M. on two successive Saturdays. This extraordinary circumstance was cleared up in a manner that need not here be explained, except on the ground of pure "accident." The same remark applies to Leeds.

The presence of sulphuretted hydrogen may in all cases be taken to indicate an intermittent flow, in some parts of the sewers, arising from some local deposit. There the sewage will remain, and, decomposing, produce that gas. Its presence, therefore, indicates defective sewers. At Coventry and Halifax we have constantly detected it; and also in a lesser degree at Nuneaton and Bradford (Yorkshire).

The value of the sewage in a commercial point of view will depend on the number of water-closets, the amount of water supply, and the social habits of the people, of course setting aside the question of rainfall, which we have yet considered as entirely unnoticed. Thus, from lengthened experience, we consider that if the sewage of Leeds and Birmingham were valued at £1 sterling, that of London would be worth £3 and that of Leamington about £10 for any specified quantity in ratio. This result has been arrived at by actual trial of manurial properties in the field, and very nearly agrees with the relative proportion of closet produce and water supply. Leeds has a great water supply and few closets; while Leamington has small water supply and a large proportion of closets in relation to the population.

An experienced eye may lead to a judgment of the manurial value of sewage with an accuracy scarcely to be expected, independent of chemical analysis. Avoiding the abnormal conditions of the sewage just referred to as arising from "washing-days," it will be found that the richer the sewage the longer will it retain, on its surface, bubles caused by shaking it up in a glass vessel. Even the action of the wind on its

surface is an indication. If the edges of the ripples are round, the sewage is rich in organic matter; if they be sharp the sewage is poor. These facts afford a rough but almost accurate indication of sewage for all purposes of utilization.

## ON THE ECONOMY SHOWN IN ROMAN CONSTRUCTION.

From the "Gazettee des Architectes" through the "Building News."

We are too ready to look upon the Romans as a people who, possessed of immense wealth, were not obliged to pay particular attention to the means by which they accomplished their ends, and who could afford without scruple to dispense with those expedients upon which we, from the insufficiency of our resources, have to rely. The passion for grand effects was not indeed entirely absent from any of their undertakings, but the genius of the Romans knew how to reconcile vast conceptions with facile means by which they might be carried out; and the more we study almost any of their remaining monuments, the more do we find artifices abounding which tend, if not to reduce hand labor, at least to simplify it. While architects in their conceptions aimed at once at a majestic effect and a durability worthy of the power of the Roman people, an evident regard to rigorous economy guided them in the execution of every part; they always aspired to realize, by the use of methods at once easy and simple, the double merit of perfect solidity and incomparable grandeur. The dominant idea which explains the practical construction of their architecture was to minimise the use of temporary staging (or scaffolding), to keep down as much as possible the cost of the centring of their vaults, and it is by the study of their concrete vaults that this idea can be put in the clearest light.

The name "vault" seems to indicate a construction, the joints of which range to a common centre. This, however, was not the method adopted in the Roman vaults formed of rubble masonry. The courses composing the body of such a vault keep, from the springing to the crown, the most exact horizontality; the sight of these courses, with clearly defined edges in the rents and fissures of a pile of ruins, recalls to the mind, almost involuntarily, the level lines which are sometimes drawn with such perfect exactness in sections of stratified geological formations. A vault was raised like an embankment, with alternate courses of stones and mortar, and the entire difficulty lay in supporting this mass of materials in space during the setting of the mortar. This difficulty was increased from another cause; since the vault owed its stability only to its monolithic structure, the least settlement of the centring, leaving these badly-consolidated masses of masonry without due bearing, exposed them to disastrous ruptures.

The following was the way in which the Romans arrived at a solution of the delicate question: instead of making the whole mass of their vaults bear directly on the temporary centring, they interposed between it and the vault an intermediate course or layer of brick (or rather tile). Sometimes a network of tile of large mesh, a sort of masonic open work of extreme lightness, is laid over the wooden centres, and takes off from them the weight of the vault proper; sometimes the temporary centring is covered over its entire surface with a layer of bricks laid flat. In either case it was sufficient, instead of making the wooden centring strong enough to carry the bulky solid of the vault, to give it the necessary stiffness to support a skeleton, by its nature light, and upon which was built the solid covering. Doubled, in fact, as the centring was by this layer of bricks, which both covered and protected it, it was sheltered from all destructive action, and while it gave its form to the mass above, did not support its weight. When once laid, this tile shell became the true centre of the vault, a centre essentially durable, which was embodied in the constructive mass, and conduced, in the same was as the masonry itself, to the solidity and preservation of the work. This second centring of tile cost, indeed, more than the equivalent bulk of the rubble or concrete the place of which it takes, but this increase of expense will appear quite insignificant if we compare it with the saving which thereby accrued in the timber—and besides this, the actual increase was but of very small amount. The materials of which the shells were composed, consisted simply of brick or tile,—of large di-

mensions, it is true, but the manufacture of which was carried on at but a small outlay in the neighborhood of Rome.

And yet these bricks, in spite of their small cost, were used with a remarkably sparing hand. We have said that the shells of Roman vaults were of two kinds: sometimes they were formed of bricks, laid as ribs radiating from the crown, sometimes they resolved themselves in a sort of curved payment laid on the centring.

Let us point out the principal variations of the first type. These were generally built with bricks of two sizes—square bricks of about 23 in. on the side, and rectangular bricks about 23 in. by 6 in. With the rectangular bricks were formed ribs, or rings, about 23 in. apart from centre to centre, and by means of the large square bricks these ribs were at intervals connected together two and two. Thus was formed round the wood centring a sort of open-work cage, which may be considered the most perfect model of a shell with ribs radiating from the crown which obtained amongst the Romans. Sometimes this envelope of the centring was replaced by a system of arches, independent of each other, and at greater or smaller distances apart. These arches were built of rectangular bricks as above, and in them were laid at intervals bricks about 23 in. square. These, projecting on each side from the rib of which they formed a part, bonded the tile mesh-work and the mass of the rubble-work closely together. Often, again, ribs formed of bricks 23 in. by 6 in. were grouped in pairs and bonded solidly together by the large square bricks forming tie-pieces.

It is difficult to give by a written description only, a clear and complete idea of the ingenious combinations of brick that were adopted. We must content ourselves here with indicating the principle of their construction, and pass on to a summary examination of the second method employed by the Romans to support their vaults—a continuous layer of flat tiles. This mode of carrying the solid vault was thus practised: On the convex surface of the centring was laid a bed of the large square bricks, the lateral dimensions of which have been already given, and which were generally from 1½ in. to 2 in. thick. These large bricks, cemented together with excellent plaster or quick-setting mortar, formed over the whole convexity of the centring a thin bed with no apertures or cavities, which exactly followed the form of the intrados, and presented, as we have above said, the appearance of a hollow tile floor. This paving constituted in itself a complete shell of the vault; but usually a second "floor" was superimposed in all respects similar to the first, but constructed of bricks of smaller dimensions, and which formed on the curved planking of the centring a double envelope cemented to the first with plaster or mortar.

As the result of this superposition, there was, over the whole extent of the centring, like a protecting crust, a sort of light vault, from which, immediately after its completion, the centring could not have been removed without running the risk of its breaking up under its own weight, but which gradually stiffened as the massive backings were filled in, and became ultimately capable of sustaining of itself the whole of the rubble work. In fact, the reason why the centring could not be immediately struck was not so much the small thickness of the solid crust as in the semicircular form of its section. A vault of flat bricks or tiles would be stable under the double condition of its section being a small arc of a circle, and of being kept immovably between fixed abutments. If formed of a semicircular section it would acquire the rigidity it lacks by the haunches being solidly filled up, which would oppose any yielding to flexure, and prevent the thin shell of masonry sinking down upon itself. This last case is evidently that of the thin crust of tile in a Roman vault.

The weight of the vault rested on the centring only until the first courses of rubble had backed up the tile paving to a level greater or less as the case might be, and the part really employed in carrying the weight, *i. e.*, the effective part of the "floor," being then a simple arc of a circle, offered itself under the best conditions for equilibrium. The wooden centring could at that moment have been struck and removed for use at some other point; in other words, the vault could be constructed in parts, and the same centring used for different portions. This is, in fact, the course which the Romans more than once followed, and to convince one's self of this, it is enough to notice that the bricks of the shell, instead of being cut to shape and forming a floor with radiating joints, have, on the contrary, their edges left square, and simply range side by side like the squares of a draught-board. This circumstance

agrees well with the idea of a construction in sections, for if we suppose the "floor" laid with joints ranging to the summit, each of these sections (or lunes) would terminate in a toothing, and thus there would be certain troublesome conditions to attend to whenever it was required to join one of them to the next; the ancients, dispensing altogether with bonding the various ribs or sections together sideways, avoided thereby all difficulties in connecting them.

As to the economy resulting in the centring, it is evident that it was sufficient, as has been already remarked, for it to be stiff enough to carry the weight of one of the two "floors." The first layer served as a centre upon which to bed the second, and the two together formed a rigid support upon which was carried the whole weight of the rough masonry.

Let us go on to the detailed arrangements and variations of the system. Sometimes were laid here and there amongst the flat bricks, bricks on edge, projecting into and giving a key to the rough backing. Often, again, the second "floor" was reduced to a series of ribs formed of small bricks laid as cover joints along the courses of the first layer. In time they were satisfied to place a small brick laid in cement on the points where a shock or a great pressure would have the most effect—that is, on the meeting point of four of the large bricks composing the mesh-work or "floor."

These shells of flat bricks or tile were in very general use amongst the Romans; the Baths of Caracalla and the Villa of Hadrian are the most remarkable standing examples. Finally the use of flat bricks in vaults has not been entirely abandoned by Italian builders. The vaulted cloisters which adorn the palaces of modern Rome are for the most part constructed of square tiles, the intrados is formed of a single layer of tiles jointed with cement, the rest is made up of very rough rubble work. Italian workmen call this sort of work *volte alla volterrana*, and sometimes give to it the expressive name of *volte a foglio*.

## CONSTRUCTIVE MATERIALS.

From "Engineering."

Of the numerous papers which are read and discussed every year by our scientific societies, but an exceedingly small number treat of the constructive materials employed by the engineer, or of the means by which these materials can be improved in quality. And yet the subject is one of vast importance, and one which can decidedly be best dealt with at meetings where practical men have an opportunity of adding to the results of their unpublished experience to those which have been formally recorded by experimenters. We are aware that in some instances a notion that trade secrets were being interfered with would prevent the communication of many facts of value; but this feeling is, we are glad to say, very far from being universal, and we believe that much good might be done by a thorough ventilation of the whole question.

The fact is that we are rapidly approaching a time when some better materials than we have now generally at our command will become an urgent necessity, for the whole tendency of engineering progress is towards imposing upon constructive materials all the strain they will bear, and in many instances more than is good for them. Civil engineers continue to plan larger and bolder bridges and similar works, while their mechanical brethren are building larger and larger engines, increasing steam pressures, and working machinery at higher speeds. Under existing circumstances there is a limit to all this, and this limit is now nearly reached in many cases. It is true that bridges of considerably larger span than any yet constructed may be built with the materials at present at our command; but this can only be done by incurring an expense which is prohibitive in any but very exceptional instances, on account of the enormous amount of material which would have to be used to obtain a limited carrying capacity. Again, by resorting to water-tube boilers, it is possible for mechanical engineers to avail themselves of steam at a far higher pressure than is now used; but such boilers are not free from objections, while the high temperature of such very high pressure steam renders lubrication extremely difficult, and causes it to exercise a destructive action on valves, pistons, cylinders, etc., which our present knowledge does not enable us to

overcome. Even with steam of ordinary pressures of 60 to 70 lbs. per sq. in., difficulties are beginning to arise from the increase in the size of engines, and this is particularly the case in marine engine practice, where a material which could advantageously replace cast iron for the construction of cylinders, and similar details would be gladly welcomed. In what we may term manufacturing engineering, too, economy of production points towards using machines capable of taking heavier cuts, and running at a higher speed; but here we are met by the difficulty of getting tools which would stand the increased work thus thrown upon them; and although Mr. Mushet, Messrs. Vickers, and other steel-makers have of late years made great progress in the manufacture of tool steel, this is a direction in which further improvement is, and always will be, acceptable.

Under these circumstances the questions to be considered are: In what direction are we to look for improved constructive materials? and How can the discovery and commercial manufacture of such materials be best promoted? To the former of these questions it is, of course, impossible to give a complete answer, although we may give some hints on the subject; but the latter may be more easily responded to. If an engineer nowadays is called upon to construct a bridge of unusually large span, or if a mechanical engineer has to make an unusually light boiler capable of standing a high pressure, he is not content with employing the constructive materials ordinarily found in the market, but specifies for steel or iron capable of resisting satisfactorily high-test strains. Under these circumstances he may obtain a material having a constructive value some 20 or even 30 per cent. greater than the average of that ordinarily manufactured, but he will, of course, have to pay for this advantage a considerably increased price. Now, although this increased price is partly necessitated by increased cost of production, it is in very many cases due to no unimportant extent merely to the fact that the demand for very high-class material is an exceptional one. The furnishing of such material, in fact, necessitates the manufacturer's departing from his usual routine of business, and hence expenses are incurred which would vanish if the demand for the very best materials was constant instead of intermittent. In other words, we believe that users of iron and steel could obtain a considerably better average quality of material at a very moderate increase of price if they would simply take the trouble to ascertain systematically the quality of the materials they employ. What is wanted is a more general abandonment of the brute strength system of construction, and a more rigid specifying of good materials combined with careful testing, to insure that such materials are supplied. With a more general demand for high-class products, there would be an increased development of the manufacture of such products, and much of the energy and skill now devoted to producing materials which are exceedingly cheap would be more profitably turned to account in manufacturing products which should be exceptionally good.

We now come to the other, and more difficult question to deal with: In what direction are we to look for improved constructive materials? And, as we have stated, any answer that we may make to it will necessarily be imperfect. There are, however, certain indications observable which seem to point out some of the directions in which progress is to be expected. For instance, at the present time almost all classes of engineers are being benefited by the vast advance which has been made during the last few years in the manufacture of steel, and few will deny the great constructive value of that material. But while this is the case there can be few users of steel who are not aware that the steel bars or plates ordinarily found in the market are composed of a vastly different material to the best steel obtainable. There are few of us who have not at some time or other had occasion to examine samples of steel prepared to illustrate the value of some particular manufacturing process, samples which would exhibit extraordinary ductility and resisting power, and which were in fact almost as superior to the best ordinary steel of commerce as that material is to the most inferior brands. Now these samples are in the majority of instances, we regret to say, not produced through any peculiar excellence in the process of which they are supposed to illustrate the value, but are simply the results of excessive care in the manufacture; and taking into consideration the great value to engineers of a material possessing the qualities of such samples, it is scarcely too much to hope that the care which is expended on these productions

may ultimately be exercised on a much larger scale and with proportionately great results. That even now steel plates can be produced on a commercial scale of a quality far superior to that ordinarily met with in the market, is proved by what Mr. F. W. Webb is now doing at Crewe, where he is making regularly Bessemer steel boiler plates having a breaking strength of 34 tons per sq. in., elongating 25 per cent. before fracture, and of such ductility that a $\frac{5}{8}$ in. hole punched in each sample strip $2\frac{1}{2}$ in. wide may be drifted out to 2 in. diameter without causing failure.

But it is not only in the general quantity of wrought steel that a vast improvement may yet be expected. We anticipate an even greater advance in the development of cast metal.

The leading steel makers in this country and on the Continent can now turn out steel castings, the production of which would have been deemed utterly impossible not many years ago, but such castings are still very far from being all that we believe they will be made. At present the excessively high temperature at which it is necessary to run the steel, and consequently the great shrinkage which takes place during cooling, is a difficulty in the way of producing castings of complex form, or having parts of very limited thickness, while the greater or less porosity of many of the castings renders them inapplicable in numerous instances where their great strength would otherwise render them especially valuable.

There appears here to be an indication that what is wanted is an alloy of steel, which should retain the strength of the latter while having a lower melting point and increased fluidity. That such an alloy, or its equivalent, will ultimately be discovered we see no reasonable reason for doubting. And here we may say that we use the word "alloy" in its broadest sense, as meaning not merely a mixture of one metal with another, but a mixture of a metal with any element, metallic or othewise. The whole subject of alloys is one of vast importance, and one which has never yet received the full attention it deserves, although many of our metallurgists and chemists, and notably Dr. Grace Calvert, have contributed much valuable information concerning it. We in fact know of no more promising field of research than that which the investigation of alloys offers, and we trust that no great time may elapse before it is more thoroughly cultivated.

An important instance of the effect exercised on the properties of a metal by the admixture of a very small percentage of a foreign substance is afforded by the "phosphor-bronze" of MM. Montefiore-Levi and G. Kunzel, and as this alloy promises to be one of the "materials of the future," we may specially advert to it here. From particulars of careful experiments with this material now before us, we find that the addition of a very small percentage of phosphorus to gun metal containing 10 per cent. of tin, increased the elastic limit about 35 per cent., and the breaking strain per square inch of the original section 80 per cent.; while one sample of phosphor-bronze, containing 6.2 per cent. of tin, had a breaking strain of over 51,000 lbs. per square inch of original section, and elongated 10 per cent. before fracture. Judging from the samples we have seen, also, the phosphor-bronze appears to be capable of making very close and dense castings, while the property it possesses of casting well in metal moulds is one of very great value in a number of instances.

It is, however, not only by the introduction of an alloy that we may be furnished with a valuable addition to our constructive materials; there is a large scope for improvement in our treatment of the materials now at our command. The experiments of Sir William Fairbairn long ago showed how greatly the quality of cast iron might be improved by successive re-meltings, while more recently Sir Joseph Whitworth has been producing some remarkable results by casting steel under pressure. The effect on steel, however, of repeated meltings, or of long continued fusion under suitable protection from oxidation, has, so far as we are aware, not been investigated, while the process of casting under pressure can scarcely be considered as fully developed, so that in both these directions there may arise improvements in the future.

It is scarcely necessary that we should dwell here upon the value of a material which should be procurable at a moderate price, be capable of being cast into even complex forms, and be possessed of a strength and ductility equal, let us say, to fairly good wrought iron. To some limited extent such qualities are supplied by malleable cast iron, but malleable castings cannot easily be made of any great size, except

perhaps, by McHaffie's method, while their liability to twist during the annealing process is in many cases a serious obstacle to their employment. If such a material as we have alluded to could be produced at a cost even as great as that of good wrought iron, the demand for it would be enormous, and there would, in fact, be few articles now built up of wrought-iron plates which could not be made of it with advantage, while it would take the place of the cheaper cast iron in an immense number of instances. The prize is one well worth trying for. Who will secure it?

## ON A NEW SYSTEM OF LONGITUDINAL SHIP-BUILDING.

By J. E. SCOTT, Esq.

From the "Journal of the Society of Arts."

Several papers have been read before this Institute and other scientific societies, having for their object the comparison of the different modes of ship-building. It is not my intention to touch upon all those different systems, but confine myself to that arrangement most commonly adopted, viz., the transverse system, as compared with my longitudinal arrangement.

There have been various plans for longitudinal construction, and a great number of vessels have been built from them; this was some years ago, but of late the transverse system has been almost entirely built from, the plan of building longitudinal ships being so much more expensive, and requiring a much longer time in construction, and as ships had not the excessive proportion of length they have now, longitudinal strength was more easily obtained than it is now possible with the transverse system.

In describing the different parts of my arrangement, I hope to be able to make clear its superiority to you, the members of this Institute.

The great economical results attained by vessels of small section in proportion to length, has induced almost every shipowner to have as long ships as possible, until there are vessels now building of eleven beams to length. The only drawback to this increase is the great additional weight required to bring up the longitudinal strength. Within the last few years there have been a great many changes in the different classification books, all tending to diminish the section for preventing transverse bending, and increase the section for resisting longitudinal bending; and even with all those improvements, I find that we have still 30 per cent. more section against transverse than against longitudinal bending. This is what I propose, by my longitudinal arrangement, to reverse. In carrying it out, I have the outside plating in longitudinal strakes, exactly as at present; but instead of having the frames transverse, I have them longitudinally, following at the stem and stern post, where those frames terminate the line of the seams of the skin plates continuously through the bulkheads, until it becomes necessary, by the diminished girth forward and aft, to gore or run two into one, and at the stem and stern post, where those frames terminate, they are connected to the corresponding frames on the opposite side of the vessel by hook-plates, thus completely connecting both sides of the vessel. These longitudinal frames, as shown in large scale section, may be formed of the usual frame and reversed angle-bars, or of Z iron, or ⊐ channel section. The spacing of those frames to be as at present, from 18 to 24 in. apart, according to the size of the vessel. From the centre line to the turn of the bilges, where we have the floor plates in transverse framed ships, I increase the longitudinal frames to the same lines as the present floors, each longitudinal forming a girder, with an angle-iron on each edge. All the longitudinal frames and girders, throughout the centire framing of the ship, will be square off the skin plates they are connected to, so that no angle-bar will require to be bevelled in any way.

Inside the longitudinal frames there are fixed to them, at spaces corresponding to every third beam, transverse, vertical tie-frames of angle-irons riveted back to back, of the same scantlings as the present keelsons, extending from the upper deck stringer-plates, and passing continuously through the lower decks, and overlapped across the centre line, and connected to the

longitudinal frames by double reverse angles. The flat of floor is additionally strengthened tranversely by means of plates let down between, and connected to the longitudinal girders, and riveted to the angle-irons of the tie-frames. In broad, flat-bottomed ships, it will be necessary to have an extra tie-frame carried up to the turn of the bilges, with plates fitted between and riveted to the longitudinal and tie-frames, so as to give the necessary transverse strength.

The beams are fitted at present across the ship at right angles to the centre line, and connected to the ship's side by double angle-iron on each knee; those beams which occur at the tie-frames have deep knees passing between, and extending from the outside of the tie-frame to the skin plates. In construction, those beams are raised with the tie-frames to preserve the form.

The bulkheads are fitted in the ordinary, manner, being let in over the longitudinals and made water-tight round them. The reverse bar may be either cut and kneed, as in the case of ordinary keelsons, or allowed to pass through. This makes up the general arrangements of iron ships.

In moulding vessels with longitudinal frames, we will have the lines and bevels for each tie-frame, also the fore and aft curve of the longitudinal frames, the breadth and curve of each plate in the outside skin; all this can be easily laid down from the body plan.

In construction, I commence by setting the centre longitudinal girder in position on the keel blocks, and then raise upon it the transverse tie frames, with their beams, securing them in the ordinary manner by ribands.

The first longitudinal frame on each side may then be bolted to the tie-frame, and the first strake of plating to them, and shored or blocked off, after which the remaining longitudinal frames and strakes of plating may be added in the same manner consecutively. In order to advance the deck work, the strake in way of each tier of beams, with the longitudinal frames, should be raised as soon as the tie-frames are in position; the beams which come between the tie-frames may then be attached to those strakes, and the stringer-plates fitted.

In order to have a comparison between the effective cross-sections of an ordinary transverse framed and longitudinal framed ship on my arrangement, I have taken a vessel of 312 ft. long by 34 ft. beam, and 29 ft. moulded to spar deck, with 3,390 tons displacement or 20 ft. 6 in. draught, or 19 ft. 6 in. from top of keel; gross tonnage, 2,000 tons; to class 100 A at Lloyd's; index numbers, Lloyd's rules, 81 and 25,194.

The scantlings of the longitudinal frames correspond with those of the present vertical frames, and those of the tie-frames to scantlings given for keelsons; all deck-stringers, beams, and skin-plates are the same in either case.

*Transverse-Framed Iron Ships.*

| | Sq. in. |
|---|---|
| Keel | 27.50 |
| Keelson angles | 67.20 |
| Centre keelson plates | 20.97 |
| Side keelson plates | 28.73 |
| Garboard strakes | 58.32 |
| Bottom plating | 236.64 |
| Side plating to lower deck | 112.84 |
| Side stringer | 34.28 |
| Lower deck stringers and tie-plates | 53.39 |
| Lower deck stringers and angles | 17.98 |
| Wood of lower deck = 1224 ÷ 16, equivalent in iron | 76.50 |
| Side plating, lower to main deck | 104.23 |
| Main deck stringer plates, ties, and diagonals. | 128.24 |
| Main deck stringer plates and angles | 24.80 |
| Wood of main deck H 1224 ÷ 16 = | 76 50 |
| Plating main to spar deck | 53.82 |
| Spar deck stringer, ties, and diagonal plates | 83.91 |
| Spar deck stringer, angles | 8.00 |
| Spar deck wood, 1224 ÷ 16 = | 76.50 |
| Greatest total area of section = | 1,335.94 |
| Deduct for rivets connecting skin plates to frames | 108.00 |
| Least total area | 1,227.94 |

*Longitudinal-Framed Iron Ships.*

| | Sq. in. |
|---|---|
| Keel | 27.50 |
| Garboard strakes | 58.32 |
| Bottom plating | 236 64 |
| Girder plates | 139.50 |
| Girder angles | 119.19 |
| Side plating to lower deck | 112.84 |
| Side longitudinal frames to lower deck | 66.22 |
| Lower deck stringer and tie-plates | 53.39 |
| Lower deck stringer and angles | 8.99 |
| Lower deck wood, 1224 ÷ 16 = | 76.50 |
| Side plating, lower to main deck | 104.23 |
| Longitudinal frames, main to lower deck | 39.72 |
| Main deck stringer, ties, and diagonal plates. | 128.21 |
| Main deck stringer and angles | 24.80 |
| Main deck wood, 1224 ÷ 16 = | 76.50 |
| Plating from main to spar deck | 53.82 |
| Longitudinal frames from main to spar deck | 39.72 |
| Spar deck stringers, ties, and diagonal plates | 83.91 |
| Spar deck stringers and angles | 8.00 |
| Spar deck wood | 74.50 |
| Greatest total area of section | 1,579.41 |
| Deduct for rivets connecting skin-plates to longitudinal frames | 66.00 |
| Least total area | 1,513.41 |

*Transverse-Framed Iron Ships.*

| | Areas | Distance from Spar deck. | Products. |
|---|---|---|---|
| | sq. in. | feet. | |
| Spar deck | 168.41 | 0.0 | 00.00 |
| Sides from main to spar deck. | 53.82 | 3.9 | 210.89 |
| Main deck | 229.51 | 7.4 | 1698.37 |
| Sides from main to lower deck | 104.23 | 11.2 | 1177.37 |
| Lower deck | 147.87 | 14.9 | 2203.26 |
| Sides to bilges to lower deck.. | 147.12 | 19.5 | 2868.84 |
| Bottom | 484.98 | 28.3 | 13724.93 |
| | 1335.94 | .... | )21883.66 |

Neutral axis below spar deck = 16.38 ft

| | Areas. | Distance from Neutral axis. | Products. |
|---|---|---|---|
| | sq. in | feet. | |
| Spar deck | 168.41 | $16.38^2$ | 45544.80 |
| Sides from main to spar deck | 53.82 | $12.5^2$ | 8409.37 |
| Sides from main to spar deck | 53.82 | $7.02^2 \div 12$ | 219.58 |
| Main deck | 229.51 | $9.0^2$ | 18590.31 |
| Sides from main to lower deck.. | 104.23 | $5.2^2$ | 2818.37 |
| Sides from main to lower deck. | 104.23 | $7.5^2 \div 12$ | 487.79 |
| Lower deck | 147.87 | $1.5^2$ | 332.70 |
| Sides to bilges to lower deck | 147.12 | $3.2^2$ | 1506.50 |
| Sides to bilges to lower deck. | 147.12 | $10.02^2 \div 12$ | 1225.50 |
| Bottom | 484.98 | $12.0^2$ | 69837.12 |
| Spar deck from neutral axis = 16.38 | | | )148972.54 |
| Moment of resistance | | | 9094.54 |

*Longitudinal-Framed Iron Ships.*

| | Areas. | Distance from Spar deck. | Products. |
|---|---|---|---|
| | sq in. | | |
| Spar deck | 168.41 | 0.0 | 00 00 |
| Sides from main to spar deck. | 93.45 | 3.9 | 364.45 |
| Main deck | 229.51 | 7.4 | 1698.37 |
| Sides from main to lower deck | 143.95 | 11.2 | 1612.24 |
| Lower deck | 183.88 | 14.9 | 2739.81 |
| Sides to bilges from lower deck | 179 06 | 19.5 | 3491 67 |
| Bottom | 581 15 | 28.3 | 16446 54 |
| | 1579.41 | .... | )26351 08 |

Neutral axis below spar deck = 16.60ft.

| | Areas. | Distance from Neutral axis. | Products. |
|---|---|---|---|
| | sq. in. | | |
| Spar deck | 168.41 | $16.6^2$ | 46407.06 |
| Sides from main to spar deck | 93 45 | $12.7^2$ | 15072.55 |
| Sides from main to spar deck | 93.45 | $7.0^2 \div 12$ | 381 27 |
| Main deck | 229.51 | $9.2^2$ | 19425.72 |
| Sides from main to lower deck | 143 95 | $5.4^2$ | 4197.58 |
| Sides from main to lower deck | 143.95 | $7.5^2 \div 12$ | 673.68 |
| Lower deck | 183.88 | $1.7^2$ | 531.41 |
| Sides to bilges from lower deck | 179.06 | $3.0^2$ | 1611.54 |
| Sides to bilges from lower deck | 179.06 | $10\ 0^2 \div 12 =$ | 1471.56 |
| Bottom | 581.15 | $11.8^2$ | 80919.32 |
| Spar deck from neutral axis = 16 6 | | | )170691.69 |
| Moment of resistance | | | 10282.63 |

*Transverse-Framed Iron Ships.—Resistance to Hogging.*

Displacement × Length ÷ 20 = 52,884 ft. tons = greatest bending moment.
9094.34 = Moment of resistance.
Greatest tension longitudinally 5.81 tons on the sq. in.
0.73 Difference of distances from neutral axis.
Greatest thrust longitudinally 4.24 tons on the sq. in.

*Resistance to Horizontal Bending.*

| | Areas. sq. in. | Multipliers. feet. | Products. |
|---|---|---|---|
| Sides | 305.17 | 17.0 = ½ breadth | 5187.89 |
| Bottom and decks | 1030.77 | 17.0 = do. ÷ 4 = | 4380.77 |
| | | Resistance to bending... = | 9568.66 |

Greatest bending moment ÷ do do..... = 5.52 tons per sq. in.

*Longitudinal-Framed Iron Ships.—Resistance to Hogging.*

Displacement × Length ÷ 20 = 52,884 ft. tons = greatest bending moment.
1028.63 moment of resistance.
Greatest tension longitudinally 5.14 tons on the sq. in.
0 71 Difference of distances from neutral axis.
Greatest thrust longitudinally 3.65 tons on the sq. in.

*Resistance to Horizontal Bending.*

| | Areas. sq. in. | Multipliers. feet. | Products. |
|---|---|---|---|
| Sides | 416.46 | 17 = ½ breadth | 7079 82 |
| Bottom and sides | 1162.95 | 17 do. ÷ 4 = | 4942.53 |
| | | Resistance to bending... = | 12022.35 |

Greatest bending moment ÷ do. do. ... = 4.39 tons per sq. in.

By reference to some tables, Mr. Scott showed that the cross-section of transverse framed vessels is to longitudinally framed vessels as 12 to 15, and that the resistance to longitudinal bending is as 9 to 10; and that the resistance to horizontal bending is as 9 to 12. This is with the same total weight of vessel, and is equal to about 15 per cent. more strength longitudinally, in longitudinally framed ships, which would enable any of our present vessels to come through any strain that they might be subjected to.

For a particular service, suppose the transverse framed vessel taken out in tables to have sufficient longitudinal strength, then take the difference between areas of sections given for transverse and longitudinal ships = 285.74 sq. in., and this divided by 960 in. = the total girth amidships = 29 in. thickness, = 11.6 lbs. weight per foot and this × length and by mean girth of vessel = 105 tons less weight required for a longitudinal vessel with my arrangement; and as the total is 900 tons, this reduction in weight is over 11½ per cent.

The advantages to be gained in construction and material are very great. The deprecatory effect caused by heating our present frame bars to the extent necessary for setting and bevelling, is well known; they become so short in the grain after being heated to such a degree, that they in many cases will not stand hoisting into their places, or even the riveting of the several parts together; this will be completely overcome by my arrangement. We will require neither the heating, bevelling, nor setting of floors, as the frames will be all square off the outside skin, and following the line of those plates, they being raised sufficiently fore and aft to take out the sag or vertical set, leaving each frame in a straight plain from end to end. Then as to the fore and aft curvature amidships, it is evident that a blow from a hammer will put this to rights; even at the ends, where the curvature increases to a maximum of 1 in 20 in the fullest ships, the beam pressing machine could put this round on with ease, as it is only twice the round given in deck beams.

Now all the skin plates can be multipliers of the same number from end to end of the vessel except the fore and after plates in each strake, which will be regulated by the length from the last butt to the stern post. This regularity is caused by there being no transverse frames to regulate the length of each plate, so that with this construction, all the longitudinal frames, girder plates, and frame holes of skin-plates, can be punched from the same template, or punched with a machine such as that used in bridge and boiler construction, with self-regulating details, thus obviating false punching, and the necessity of a separate template for each plate.

As skin-plates are of different breadths, it may be considered difficult to obtain this advantage, but as the butts do not overlap one another, they can be punched in the usual manner.

The advantage to be gained in this part of the structure is the saving of time, as all the plates and frames can be marked and punched at once, instead of having one part marked off another as at present.

In riveting the frames, it will be an easy matter to have them brought under a common riveting machine, which at present is all but impossible, from the awkward shape and weight to be carried from the machine to the ship, so that the usual mode of riveting large frames at present is across their own keels, for convenience in hoisting. Even this inconvenience and the expense of riveting may be altogether overcome by the use of Z iron or ⊐ channel iron. To obtain this advantage in the present mode of transverse construction is impossible; neither of these sections can be used, as they have to take many sharp curves and can be bevelled in many different ways.

To bring and keep longitudinally-framed vessels in shape has always been a serious difficulty. Prior to this, temporary moulds have been used. This is at once costly and insecure, therefore objectionable, but will be overcome in my arrangement by the transverse tie-frames of double angle-iron, back to back, which will be in permanent position at the beginning of construction. I may here mention that these are the only frame bars requiring to be heated and bevelled, and they amount to only ⅛th of the ordinary transverse frames. Here, also, you will observe a decided advantage in the reduction of furnace work, as the present frames cost twice the amount per ton weight of iron of any other part of the structure.

In securing the deck beams to the outside plating, the loss of the transverse frames at this point will be made up by double angle-irons on the beam knees, as the connection does not in any great measure depend on

the knee, but to a large extent on the stringer plates and bar. The difficulty and great expense of connecting deck stringers to the outside plating on deck, where the frames pass through the stringers, will be removed by the bars being continuous fore and aft, and not cut into short pieces between the frames, as at present. This connection is very necessary, to prevent straining at the decks.

By having the bulkheads in direct contact with the skin, as in transverse framed ships, it becomes a very rigid part of the structure, and, instead of strengthening, tends to weaken, on account of the skin-plates being pierced so close in order to make the connection secure, the rigidity being only diffused by the keelsons and stringers; but by having the double angle-iron frames inside the longitudinal frames, we disperse the rigidity fore and aft of the bulkhead over a large area, and, instead of weakening the skin at one point, it gives strength to all around by having the longitudinal frames passing continuous through the bulkhead, and making it water-tight round them by fitting plates between the longitudinal frames, and connecting them to the skin and bulkhead frames by angle-irons. There is, therefore, no necessity for having the skin doubled, as at present, at this point to assist in keeping the bulkhead from working, as there is no direct strain on the skin-plate. The only use of plates between the longitudinal frames is to cut off the connection between one hold and another.

It is very requisite at the ends of vessels to have one side thoroughly connected with the other, especially so in screw steamships, where the vibration caused by the propeller being suddenly thrown in and out of the water is very severe; the best workmanship and materials are often found insufficient to cope with this for any length of time. Now, with transverse frames this part of the structure is in no way strengthened, for not only are they almost always reduced in the inner flange to admit of the stern-pipe being got into its proper place, but are altogether in the wrong position to hold out against this strain. To meet the vertical strain on this point, we have the whole length of the stern-post above and below the shaft connected to the plating, thus diffusing it thoroughly in this direction; but to meet the horizontal we have only the cross section of the stern-post, skin-plates, and water-tight iron deck. As the transverse vertical frames are completely disjointed in a horizontal direction by the impossibility of introducing keelsons at this point in such a contracted space, we cannot allow anything for them. It is clear, I think, that this horizontal strain is met in a very insufficient manner; but with longitudinal framing we shall be able to completely overcome this inequality in rigidity by having a series of iron deck, as it were (as shown in plate), above and below the shaft, thus completely connecting the skin plates from side to side, and adding to the horizontal resistance. There will also be greater facility for riveting the skin, as those horizontal plates can be fitted after the skin-plates are in position, and riveted. At the fore end of the vessel there are numerous advantages to be gained by having the sides of the vessel so thoroughly connected horizontally, and giving support to the stern, which, at present, is only supported by the skin-plates and stringers.

Water ballast tanks so greatly promote economy in shifting from port to port that they are every day becoming of more importance. They are with difficulty constructed in a satisfactory manner with transverse frames, because of the frames having to be cut on each side or allowed to pass through the side-plate of the tank at such close intervals, the difficulty being to make it water-tight round each frame.

In the first construction we sacrifice the frame, in the other we weaken the side of the tank in order to preserve the frame. With transverse frames this is imperative, but if we have the frame running in the same line as the side of the tank, then we obviate all this unnecessary and unsatisfactory work. Water ballast tanks can be constructed in longitudinally framed ships with the greatest ease, and assurance of being tight when completed, by a very simple arrangement, as shown on plate. The side-plate of the tank is attached to one of the longitudinal frames, making a plain caulking seam fore and aft with the outside plating, which has no interruptions whatever, and all plain work from end to end, instead of the many interruptions and small detached pieces that are necessary in transverse framed ships; this is the part that makes those tanks so expensive and troublesome to construct. We shall be able to entirely dispense with those heavy

knee-plates that connect the frames to the side-plate of the tank.

The transverse tie frames pass through the side-plate of the tank, but as they are clear of the side of the ship there is every facility for making the tank-plate tight round them. To have the wash from one side to the other stopped is one of the most particular points in the construction of those tanks: if the water is allowed to wash from side to side, the pressure brought to bear on the side-plate is so great that it is impossible to keep them tight; this is entirely prevented in longitudinal framed ships. If it is necessary to end the tank before reaching the ends of the vessel, it can be made perfect by having a bulkhead fitted across, in the same manner as the others.

The small number of composite ships now building shows a serious defect somewhere; either they must be weak for the quantity of material per ton, or, when strong enough, they are too costly. By studying our present composite ships, it is apparent that they have too little longitudinal strength as compared with an iron ship. We have in composite ships the transverse frames, floors, beams, and keelsons, all of much the same scantlings as in iron ships, and on those frames are bolted the longitudinal strakes of planking. In my arrangement for composite ships I have the external outside planking worked diagonally, which may be either of one or two thicknesses, according to the size of the vessel. The longitudinal frames, transverse tie-frames, and deck beams, are all fitted in the same manner as described for iron ships on this principle.

As the longitudinal frames require to be united at their outer edges as well as at their inner edges, I have narrow flat-plates from keel to gunwales, crossing the longitudinal frames at each of the transverse tie-frames. Those plates are connected to the plates between the longitudinal frames in flat of bottom by angle-iron on their lower edges. At the centre line a strake of plating is applied, running fore and aft, sufficiently broad to embrace the garboard strakes, and the butts of the diagonal planking. The keel, stem, and stern-post are also bolted to this plate, as at present. At each bilge there is a strake of plating fitted, embracing two of the longitudinal frames, and extending over $\frac{3}{5}$ths of the ship's length amidship; and in the line of each tier of beams it is necessary to have similar strakes for connecting the beam-knees and stringer-plates to the frames.

In construction all the longitudinal frames will be secured to the tie-frames and outside tie-plates, and also the longitudinal strakes of plating in their proper positions, before putting on the diagonal outside plating, as each diagonal strake crosses all the longitudinal frames.

The advantages gained in frame setting, punching, and riveting, in iron-clad ships with my arrangement are likewise obtained in composite ships.

The whole structure will be much more rigid than with the present transverse frames, by the outside planking, passing diagonally across the frames, resisting at the same time transverse and longitudinal bending, also, giving great stiffness at the bilges, which at present are only supported by the transverse frames and bilge keelsons.

To show more distinctly the advantages to be gained as to strength by the frames being longitudinally, I have taken out the section of a vessel 200 ft. long by 34 ft. broad, and 22 ft. moulded; tonnage under-deck 898 tons; displacement 2,050 tons, on 19 ft. 6 in. draught of water, or 18 ft. from the top of the keel, to class 100 A at Lloyd's.

In making up those sections I have taken the same scantlings for longitudinal frames as required by rules for transverse frames and for my transverse tie-frames I have taken the scantlings given in rule for keelsons.

*Composite Transverse-Framed Ships.*

| | |
|---|---|
| Keel wood, 342 ÷ 16 | 21.37 |
| " plate | 24.30 |
| Bilge strake | 27.28 |
| Planking of bottom wood = 2160 ÷ 16 | 135.00 |
| Keelson angles | 54.00 |
| " plates | 52.60 |
| Planking from bottom to lower deck, wood 1584 ÷ 16 | 99.00 |
| Diagonal plates on frames between lower deck and bottom | 6.82 |
| Keelson angles | 18.00 |
| Wood of lower deck, 1224 ÷ 16 | 76.50 |
| Stringer and tie plates of lower deck | 42.16 |
| " angles | 9.00 |
| Planking from main to lower deck, 924 ÷ 16 | 57.75 |
| Iron sheer strake | 20.46 |
| Diagonal plates or frames | 6.82 |
| Wood of main deck = 1584 ÷ 16 | 99.00 |
| Main deck stringers, ties, and diagonal plates. | 65.72 |
| " " angles | 9.00 |
| Total area | 824.78 |
| Deduct for rivet connecting plates to frames | 18.00 |
| Least total area | 806.78 |

*Composite Longitudinal-Framed Ships.*

| | |
|---|---|
| Keel, wood, 349 ÷ 16 | 21.37 |
| " plate | 24 30 |
| Bilge strakes | 27 28 |
| Wood planking of bottom = 2160 ÷ 16 | 135.00 |
| Longitudinal web plates | 152 00 |
| " " angles | 178.76 |
| Wood planking from bottom to lower deck, 1584 ÷ 16 = | 99.00 |
| Iron lower deck sheer strake | 10 50 |
| Longitudinal frames from bottom to lower deck | 87.00 |
| Wood of lower deck 1224 ÷ 16 | 76.50 |
| Lower deck stringer and tie plates | 42.16 |
| " angles | 9 00 |
| Planking from lower to main deck, 929 ÷ 16 | 57 75 |
| Iron sheer strake | 20.46 |
| Longitudinal frames between main and lower deck | 43 50 |
| Wood of main deck, 1584 ÷ 16 | 99 00 |
| Main deck stringers, ties, and diagonal plates | 65 72 |
| " " angles | 18.60 |
| Total area | 1,167.30 |
| Deduct for rivets connecting plates to frames | 15 00 |
| Least total area | 1,152.30 |

*Composite Transverse-Framed Ships.*

| | Areas. | Distance from Main deck. | Products. |
|---|---|---|---|
| | sq. in. | | |
| Main deck | 173.72 | 0 0 | 000.00 |
| Sides from main to lower deck | 85.03 | 3.75 | 318.86 |
| Lower deck | 127.66 | 7.50 | 957.45 |
| Sides to bilges from lower deck | 123.82 | 12 50 | 1547.75 |
| Bottom | 314 55 | 22.22 | 6991.02 |
| | 824.78 | ) | 9814.88 |

Neutral axis below main deck = 11.90 ft.

| | Areas. | Distance from Neutral axis. | Products. |
|---|---|---|---|
| | sq. in. | | |
| Main deck | 173.72 | $11.9^2$ | 24600.49 |
| Sides from main to lower deck | 85.03 | $8.1^2$ | 5441.92 |
| Sides from main to lower deck | 85.03 | $7.5^2 \div 12 =$ | 398.57 |
| Lower deck | 127.66 | $4.35^2$ | 2415.32 |
| Sides to bilges from lower deck | 123.82 | $11.00^2 \div 12 =$ | 1248.51 |
| Sides to bilges from lower deck | 123.82 | $0.70^2$ | 60.67 |
| Bottom | 314.55 | $9.30^2$ | 27205.42 |
| | | | 61370.90 |

Main deck from neutral axis = 11.90 ft.

Moment of resistance..... 5157.73

*Composite Longitudinal-Framed Ships.*

| | Areas. | Distance from Main deck. | Products. |
|---|---|---|---|
| | sq. in. | | |
| Main deck | 182 72 | 0 | 000.0 |
| Sides from main to lower deck | 121 71 | 3.75 | 456.41 |
| Lower deck | 127.66 | 7.50 | 957.45 |
| Sides to bilges from lower deck | 196.50 | 12.50 | 2456.25 |
| Bottom | 538.71 | 21.50 | 11582.26 |
| | 1167.80 | ) | 15452.37 |

Neutral axis below main deck = 13.23 ft.

| | Areas. | Distance from neutral axis. | Products. |
|---|---|---|---|
| | sq. in. | | |
| Main deck | 182.72 | $13.23^2$ | 31981.48 |
| Sides from main to lower deck | 121.71 | $9.50^2$ | 10984.32 |
| Sides from main to lower deck | 121.71 | $7\ 50^2 \div 12$ | 569.60 |
| Lower deck | 127.66 | $6.00^2$ | 4595.76 |
| Sides to bilges from lower deck | 196.50 | $11.00^2 \div 12$ | 1980.72 |
| Sides to bilges from lower deck | 196.50 | $1.00^2$ | 196.50 |
| Bottom | 538.71 | $7.70^2$ | 31940.11 |
| | | | 82248.49 |

Main deck from neutral axis = 13 23 ft.

Moment of resistance..... 6216.81

*Composite Transverse-Framed Ships.—Resistance to Hogging.*

Displacement × Length ÷ 20 = 25,000 ft. tons = greatest bending moment
5157.73 = moment of resistance.
Greatest tension longitudinally 4.84 tons per sq. in.
.78 difference of distances from neutral axis.
Greatest thrust longitudinally 3.77 tons on the sq. in.

*Resistance to Horizontal Bending.*

| | sq. in. | | | Products. |
|---|---|---|---|---|
| Sides | 208 85 | 17 ft. = ½ breadth | = | 3550.45 |
| Bottom and decks | 615.93 | 17 ft. = do | ÷ 3 = | 3429 85 |
| | | | Resistance to bending... | 7040.30 |

Greatest bending moment ÷ do. do = 3.55 tons per sq. in.

*Composite Longitudinal-Framed Ships.—Resistance to Hogging.*

Displacement × Length ÷ 20 = 25,000 ft. tons = greatest bending moment.
6216.81 = moment of resistance.
Greatest tension longitudinally 4.02 tons per sq. in.
.58 differences of distances from neutral axis.
Greatest thrust longitudinally 2.33 on the sq. in.

*Resistance to Horizontal Bending.*

| | sq. in. | | | Products. |
|---|---|---|---|---|
| Sides | 318.21 | 17 ft. = ½ breadth | | 5409.57 |
| Bottom and decks | 849.09 | 17 ft. = do. | ÷ 3 = | 4810.94 |
| | | Resistance to bending | | = 10220.51 |
| Greatest bending moment ÷ | | do. | do. | = 2.44 tons per sq in. |

The difference, as shown in those tables, between the cross-sections of composite transverse and composite longitudinal ships is very great. They are as 8 to 11, and the resistance to longitudinal bending is as 5 to 6, and that of horizontal bending as 7 to 10.

## THE MEASUREMENT OF SHIPS.

From "Naval Science."

"Merchants and sailors are continually asking, what will a ship carry? or, of how many tons is she? and naval architects or tonnage-measurers constantly supply the answer; but almost always it is doubtful whether the tons spoken of in expressing the size of a ship are weights or measures, so that very often weight and volume, although so different from one another, are confused." These words were written more than a century ago, and are very nearly as true now as then. The subject of tonnage, or measurement, may still be fairly described as one to which "few persons, not naval architects, attach any distinct idea;" and the want of better knowledge amongst persons having an interest in shipping is attributable, not to any inherent difficulty or complexity in the systems of measurement, but rather to the confusion incidental to the use of the same term "ton" as a unit of measurement in at least four different senses. Moreover, we are unaware of the existence of any brief description, in popular language, of the various methods of measuring tonnage now in use, although it is not uncommon to hear inquiries after information of the kind. In this article our endeavor will be to furnish such a description, which we venture to hope will not be without interest, especially at a time when the old-established system of tonnage measurement for the ships of the Royal Navy has so recently been supplemented by another and better method.

The necessity for some mode of measuring the sizes of ships, either for purposes of comparison, or of estimating the cost of construction, or of computing the various dues and duties from time immemorial levied upon shipping, must have been felt at a very early period. In some ancient documents, statements occur of the "tonnage" or "portage" of ships; but it is practically impossible to settle conclusively how this tonnage was calculated. There is reason to believe that it was based upon some rough approximation to the number of butts, or *tuns*, of wine which a vessel could carry, and that from this custom the term "tonnage" was derived. It is interesting to note that, if this is a correct view, this earliest system of measurement was based upon units of *volume*, and not upon units of *weight;* in which particular it resembles the system still in use for merchant shipping. The number of butts of wine that could be carried in the ship depended, of course, upon her capacity; and it is natural to suppose that at first this number would be determined tentatively. But, as experience became more enlarged, there must have arisen a desire to arrange some better and less laborious method of settling the tonnage without actually stowing the hold; and so some method of calculation, giving a fair approximation to the carrying power of the ship in terms of her principal dimensions—length, breadth, and depth—must have been devised. An empirical formula of this kind once established in use would, doubtless, work satisfactorily, and give very fair results so long as the types of ships, their forms and proportions, and their methods of construction, remained unchanged; but, resting upon no scientific basis, it might, if desired, be evaded by various devices, and might, in course of time, become an evil which could not be longer borne with.

The well-known rule for tonnage by "Builders' Old Measurement" (or, shortly, B. O. M.) furnishes an example of the preceding statements. Its use in measuring British shipping can be traced back for centuries; until 1836 it remained established by law as the only recognized system for the merchant service; and, until a few months ago, it was the only tonnage meas-

urement for H. M.'s ships given in the "Navy List;" while, at the present time, it is still recognized in the official lists and returns for both our own and the American Navy. Private shipbuilders, too, still make some use of this old rule in estimating the cost of ships; and, in a slightly modified form, it is employed as the basis of measurement by most yacht clubs. Yet, strange to say, it is a most unscientific and misleading method of calculating tonnage, and has been shown again and again to be most objectionable, hampering the designers of ships very seriously, and leading to the adoption of bad forms and proportions.

The only argument that can be advanced in favor of the Builders' Old Measurement is the shortness and simplicity of the rule by which it was calculated; this may be summarized as follows:

The *length* was taken on a straight line along the rabbit of the keel of the ship, from the back of the main-sternpost to a perpendicular line from the forepart of the main-stem, under the bowsprit. The breadth was taken from the outside of the outside plank in the broadest part of the ship, exclusive of any additional thickness of planking or doubling strakes that might be wrought at that part. Then from the length was subtracted $\frac{3}{5}$ths of the breadth, the remainder being termed the "length for tonnage."* This was multiplied by the breadth, and their product by half the breadth, and, dividing by 94, the quotient expressed the tonnage. †

It would appear that this rule was intended to express two principal assumptions:—First, that by the deductions made in finding the so-called length for tonnage, allowance was made for the fineness of form of the ship, as compared with the circumscribed parallelopipedon; and, secondly, that the depth might be fairly taken as one-half the breadth. Nothing need be added to this simple statement to show the utter want of any scientific basis in the rule; it stands confessedly only as a "rule of thumb," and could be evaded with comparative ease. Builders and owners, alike desirous of producing ships of small nominal tonnage but of great cargo-carrying capacity, were not slow to perceive that this policy required the use of raking sternposts and other small devices, but was, above all, favored by the adoption of deep and narrow ships; and to this policy they sacrificed considerations of safety, behavior, and, generally, good performance. It has been well said, that before the abolition of the old law "the ships became little more than oblong boxes, most dangerous as seaboats, and, from their want of stability, not capable of carrying sufficient sail to insure their safety on lee shores. Hence, after every gale of wind, the leeward coasts were covered with their wrecks; and hence Lloyd's books registered annually the loss of six ships in four days." It is no wonder that in face of such disasters, and their obvious cause, the tonnage law should have been abolished; but it may well appear strange that for more than 30 years after its abolition, so far as the merchant service was concerned, it should continue in use in the Royal Navy, and should still be the basis of the Thames' measurement for yachts.

In the last-mentioned rule some slight modifications are made which require notice. The length is measured on the deck from the fore part of the stem to the after part of the stern post, and so any evasion of the rule by *raking* the post, as builders formerly did when the B. O. M. rule was in force, is rendered impossible. The breadth is measured at the broadest part, wherever found. Then from the length is subtracted the breadth (instead of $\frac{3}{5}$ths the breadth), and the length for tonnage thus determined is multiplied by the breadth, their product by half the breadth, and the quotient of the final product is divided by 94; this gives the tonnage by Thames' measurement It is, of course, obvious that in the constructions of yachts there are not temptations to sacrifice form, speed, and good qualities to mere carrying capacity, such as formerly existed in merchant shipbuilding; the exact reverse is true, and great sail-carrying power, necessitating considerable stability, is a *sine qud non*. But, on the other hand, it does seem a matter for regret that a rule of measurement so confessedly imperfect should be continued in use, when a better might be found. Into this matter, however, we cannot enter here.

* It will suffice to add that if the ship was measured when afloat a somewhat different plan was adopted, and another small deduction of 3 in. for every foot of the load draught of water was made in estimating the length for tonnage, this latter deduction being intended to allow for the rake of the sternpost.

† In algebraical language, if L = measured length, B = breadth

$$\text{Tonnage B. O. M.} = \frac{\left(L - \frac{3}{5}B\right) \times B \times \frac{B}{B}}{94}.$$

The Americans also make use of a modification of the B. O. M. rule in calculating the tonnage of their war-ships, when they are of unusual form like the monitors, although for their frigates, corvettes, sloops, etc., they appear to leave the old rule unchanged, just as has been the custom in the Royal Navy. In extremely broad shallow vessels, like the monitors, where the depth is actually much less than half the breadth, the American designers appear to use the actual depth instead of the half-breadth in the continued product, which, when divided by 94, gives the tonnage. This they appear to call "New Tonnage," and the rule is free from one of the objections to which the B. O. M. rule is open; but even with this modification it is far from satisfactory, and it affords no fair means of comparison.

In our "Navy List," as was said before, the old measurement still appears, although now not alone. The fact is not a little singular when it is remembered that every one considers the merchant service to have been much benefited by the abolition of the old law, and that for years past there has been an almost continual agitation in favor of a change. Sir Spencer Robinson and his professional advisers strongly advocated this course some years ago, and exposed the evil effects of the old system.* A similar course was recommended by the professional witnesses examined by the recent Admiralty Committee on Designs, who, having the facts before them, finally reported in favor of the oft-repeated proposal to use displacement instead of Builders' Old Measurement, and moved the Admiralty to make a long needed change.

It has been asserted that the non-existence of any temptation to make the nominal tonnage of our war-ships small at the expense of their good qualities, has rendered the continuance in use of the Builders' Old Measurement comparatively harmless, and there is doubtless some truth in this statement. But, on the other hand, it cannot be denied that the practice has had some evil consequences, especially when it was associated with absurd limitations as to the maximum tonnage of ships in particular classes. All writers on our naval history appear to agree that this fact had something to do with the long-continued superiority of the French ships to our own during the latter half of the last century, and it is not a little remarkable that during the present century every marked change or improvement in the construction of the ships of the Royal Navy has been accompanied by a protest against, or a disregard of, the pre-existing tonnage limitations. This was especially true of Sir William Symonds when Surveyor of the Navy; it was true also of the Chatham Committee on Designs, Messrs. Read, Chatfield, and Creuze; it was true of the steam reconstruction; and in perhaps the most marked degree true of the iron-clad reconstruction, the tonnage of the Warrior being something like 50 per cent. greater than that of the largest steam line-of-battle ships. It is needless to add that in the later stages of the iron-clad reconstruction the use of this defective rule of measurement has not been unattended with difficulty. Cases have occurred where the imposition of a tonnage limitation has necessitated the sacrifice of some important quality, without which the efficiency of the type could not be considered unimpaired; and other cases are on record where the professional officers of the Admiralty have had to state plainly that, under the tonnage limitation imposed, it was quite impossible to obtain all, or nearly all, that was desired in armor, armament, and speed.* On all accounts, therefore, it is a matter of congratulation that the first step has been taken towards abolishing the vicious system of Builders' Old Measurement as applied in the Royal Navy.

Resuming our sketch of the history of British tonnage regulations, a few words must be said respecting the law which replaced the Old Measurement in 1836, and remained in force for nearly twenty years. The intention of this Act was to obtain, by actual measurements taken in the hold of a ship, some idea of her internal capacity, and to make this the basis of the legal tonnage. In *principle*, therefore, it resembled the Tonnage Law which superseded it in 1854, but the measurements taken were very few, and the whole system was very imperfect, so that the shipbuilder was easily able to evade the regulations, and in some cases is said to have secured a reduction of 10 or 15 per cent. in the nominal tonnage by various simple devices. One favorite method was to work thicker ceiling, or by other means

*See the Report of the Parliamentary Committee of which Mr. Seely was chairman.

*For cases in point readers may refer to the Parliamentary Papers containing the Report, Evidence, etc., of the recent Committee on Designs.

to narrow the ship's hold locally, at the few stations where the Act required the measurements to be taken, filling her out between. There was no similar temptation, however, under this law to malform the exterior of the ship herself, such as existed under the preceding rule, and the contrast is most marked when it is considered that the law of 1836, although faulty, was sound in principle, resting upon the assumption that the determination of the internal capacity of a ship was the fairest system of measurement for all fiscal and commercial purposes.

It is interesting to notice that this same principle had been laid down 150 years before in the French "Ordonnance de la Marine for 1681," which provided for the approximate measurement of the internal capacity of ships, allowed a margin of 2½ per cent. on the result of the measurement as a maximum error, and stipulated that 42 cubic feet should be reckoned to the ton. In its conception this old law—probably long obsolete—is quite as sound as our present Tonnage Law, although, in its mode of executing the measurement of the internal capacity, it was far inferior to the present rule. M. Bouguer, who initiated so many practices which have since been generally adopted, fully realized this defect of measurement, and recommended that, to insure accuracy, the internal capacity should be calculated by a process similar to that which he used for finding the volume of displacement for a ship. Here, strange to say, he anticipated Mr. Moorsom, the late Surveyor-General of Tonnage, who, when it was a question of improving the Tonnage Law of 1836, made a suggestion similar to Bouguer's, only still more accurate in its execution, for calculating the internal capacity of ships, in order to obtain their tonnage.* We have never seen this fact mentioned in any work, and it can scarcely fail to interest our readers to know that the system of measurement of the Tonnage Law of 1854, which is usually referred to as a novelty, had been so clearly enunciated a year before, although the fact was possibly unknown to those who framed the Act.

Passing next to the so-called "Register Tonnage" measurement, initiated in 1854 by Mr. Moorsom and his colleagues, and since used not merely in our own mercantile marine, but also in that of many other countries, our task of explanation will be a light one. It is only proper at the outset to acknowledge most fully the great advantges that have resulted from the introduction of this measure, and the great judgment and foresight displayed by those who framed the regulations, which, with some very trifling modifications, have continued in use ever since, and given general satisfaction.

Register Tonnage is defined by Mr. Moorsom as "simply the internal capacity of the hold of the ship in cubic feet, divided by 100 in order to bring out, with any additional spaces built upon deck, as nearly as may be the aggregate of the nominal tonnage of former laws, so that the statistical tonnage of the kingdom should remain unaltered, as well as all revenues which, from early times, may have been founded on that standard. *It is hence seen that the nominal ton of the present law consists simply of* 100 *cubic feet.*"

No one can fail to understand, in face of this brief and simple explanation, what is meant by a "ton" of Register Tonnage; but it would be difficult for any one to interpret what is meant by a ton of Builders' Old Measurement tonnage. Besides being intelligible and scientific, the new system of tonnage measurement has the advantage of affording the shipowner information of which he is constantly in need; for, knowing the Register Tonnage, he knows also how many cubic feet are available for stowage of cargo and passenger accommodation, and thence can easily arrive at the *dead-weight* which the vessel may be expected to carry under ordinary conditions of service. This translation of units of volume into units of weight is necessarily based upon experience, for the very miscellaneous character of an ordinary cargo, and the want of anything like uniformity in the character of the successive cargoes carried in the same ship, prevent any mere theoretical estimate from being of much value. Experience shows, however, that in ships provisioned and stored for an average length of voyage, about 67 cubic ft. is the space required for each ton (avoirdupois) of cargo carried; or, as it may be otherwise stated, that each ton of Register Tonnage (100 cubic ft.) will, on an average, suffice to carry 1½ tons weight of

* Readers familiar with such calculations will understand the difference between Bouguer's and Moorsom's methods, when it is stated that the former used the *trapezoidal* rule and the latter one of Sterling's or Simpson's rules for parabolic curves.

cargo. On this experimental fact Mr. Moorsom bases the following simple rule:

"To ascertain approximately the dead-weight cargo which a ship can safely carry on an average length of voyage. . . . . it is only necessary to multiply the number of register tons under her tonnage deck by the factor $1\frac{1}{2}$."

This factor ($1\frac{1}{2}$) makes allowance for deductions necessary to be made for provisions and stores, but does not allow for the spaces appropriated to passenger accommodation, which are obviously very different in different ships, and must be separately deducted in each case.

The new system at first met with much opposition, on the ground of the complexity of the calculations it required, and the largely-increased number of measurements which were made from each ship. The objection was not valid, and could only have been made by persons ignorant of the principle of calculation, or desirous of retaining the power which they possessed under preceding regulations, of easily evading the law. From the first, disinterested and better-informed persons were strongly in favor of the new system, which rendered evasion by any small devices practically impossible, and removed all temptation to use bad forms and proportions for the sake of securing small nominal tonnage with great cargo-carrying power. Its beneficial effects have since been so fully proved as to place the matter beyond dispute, and to render it difficult to believe that such objections as those named above could ever have been made against a plan combining accuracy with simplicity in such a marked degree. Its principle has been accepted, too, by most maritime nations of importance; and although our method of measurement of the internal capacity is not adopted by all, the final result is very nearly identical, and the capacity-ton, or unit of measurement in the merchant navies of the United States, France, Russia, Italy, Belgium, Spain, and Denmark, is in no case more than 10 per cent. different from our register ton, the difference in most cases being much less.*

As the result of nearly twenty years' experience of the working of the Tonnage Law of 1854, it would appear that only one important point is in dispute, and this had become manifest twelve years ago, but has not yet been settled, nor does it seem approaching settlement. This is the vexed question of "nett" as distinguished from "gross" tonnage, especially in steamers, which has of late been brought into unusual prominence by the action taken by the Suez Canal Company, who have departed from the common practice, and charged dues upon the gross tonnage instead of the nett.

"Gross" register tonnage is the cubic content (in units of cubic ft.) of the hull of a ship and of every covered-in space upon the upper deck; "nett" register tonnage is intended to express, in the same units, the cubic content of the space actually available for remunerative service, the conveyance of passengers, or stowage of cargo. In sailing ships the difference between gross and nett tonnage is scarcely appreciable, the only deduction from the gross being that for the space occupied by the crew, made on the basis of a minimum allowance of 72 cubic ft. per man. In steamers, however, the case is very different, for, in addition to the crew-space, deductions are made for the space occupied by, or required for the efficient working of, the machinery; and these deductions are very considerable indeed in some cases, making the nett tonnage, say, not more than 60 or 70 per cent. of the gross, and sometimes much less than this. As an extreme case we may refer to one of the Holyhead packets, the Leinster, which, as is well known, has very exceptional steam power and is extraordinarily fast. The gross register tonnage of this vessel is 1,382 tons, her nett tonnage is only 385 tons—about 28 per cent. only of the gross tonnage—this large deduction being due to the great space occupied by the machinery. Other instances are on record where tugs, with very great engine power, have, by means of the deductions for the engine space, etc., been made practically to have *no* tonnage, or to be within 1 per cent. of a negative tonnage. These are, of course, exceptional types, but even in ordinary ocean-going steamers the deduction for machinery space is very considerable, and is by no means free from objection.

This deduction, according to Mr. Moorsom, is made on the principle, "That an allowance ought to be made for the space occupied by the machinery, which is a fixed and serious abstraction from the capacity, but not for fuel, except to the particular extent hereinafter mentioned, as fuel can

* In the very valuable work on "Stowage," by the late Mr. Stephens, of Plymouth, some very interesting information on this subject will be found.

only be considered as an ever-varying adjunct for working the machinery, varying with every length of voyage, in the same manner as the provisions, water, and stores for excess of crew, spare gear, sails, and canvas, with various other items, are the necessarily varying adjuncts for working the sails, which constitute the propelling machinery of sail-vessels, and for which no allowance is made to sail-vessels." The coal space here referred to is that on each side between the machinery and the ship's sides, which from its situation was considered unfit for any other purpose, such as the stowage of cargo. With the intention of preventing unnecessary enlargement of the machinery space in order to decrease the tonnage, it was provided in the Act of 1854 that, subject to the approval of both the Customs authorities and the shipowner, instead of actually measuring the machinery space, etc., it should be allowed for by certain percentages on the gross tonnage; and at the present time, after various emendations and alterations of this part of the law, we believe the regulations stand much as when they were first issued. This is rather to be wondered at, seeing that the "anomalous workings" of the system of percentages, and the possible evasions of the intention of the Act which resulted, were frankly acknowledged by Mr. Moorsom in 1860; his recommendation then being that, instead of making a percentage allowance, actual measurement of the engine-room should be had recourse to, provision being made to prevent the undue extension of that space. It should be added that in the Merchant Shipping Code introduced, but not passed, last year, regulations were embodied practically carrying out Mr. Moorsom's suggestion; and it may fairly be assumed that these regulations sum up the result of official experience during the time the Act of 1854 has been in force. In this code it was provided also that, except in the case of tugs, the deduction for engine-space, etc., should not exceed 50 per cent. of the gross tonnage; actual measurements being made of the volumes of engine and boiler-rooms, coal-bunkers, shaft-passages, funnel-casings, etc., for the deduction in cases where this limit was not reached. This alteration will undoubtedly commend itself to the minds of most persons interested in the subject, who consider that allowance should be made for the space occupied by machinery, or thereby rendered unfit for cargo.

On this last-named point opinions are however, far from being identical. From the first introduction of steamers there have not been wanting high authorities who disputed the fairness of making any such allowance to steamers, and favored the course, now put into practice by the Suez Canal Company, of taking gross register tonnage as the basis of computing Customs and other duties. The balance of opinion is undoubtedly on the other side, and general practice sanctions the soundness of the view that only the commercially-remunerative space, available for cargo or passengers, should be charged with dues or duties. At the same time it cannot be denied that, from the point of view of the proprietary of docks, canals, or other establishments furnishing accommodation to shipping, there must appear great anomalies in the common system of charge. The accommodation which a ship requires, the space she occcupies, and the difficulty of moving and handling her, all depend upon her external dimensions and size, which are obviously not so well indicated by the nett register tonnage as by the gross. For example, taking a sailing ship and a steamer each of 1,400 or 1,500 tons burden by nett measurement, it would be found that the gross measurement of the steamer would be quite 2,000 or 2,100 tons if she were full-powered, while the gross measurement of the sailing ship would differ but little from the nett. There can be no question, we think, that the system can scarcely be regarded as perfect which would only require the same payment for the accommodation in a dock or in a canal of these two ships, differing as they must do greatly in their size, weight, and handiness.

Nor can it be denied that, while the use of steam-propulsion necessitates a very considerable decrease in the cargo-carrying power of a ship, it is by no means an unmixed disadvantage. Less cargo is carried, but the transit is more rapid, a much higher rate of freight is obtained in consequence, and, in very many instances, a remunerative passenger traffic is secured besides. These advantages are, of course, attended by largely increased working expenses, much larger original outlay on ship and machinery, and greater cost of maintenance; and it would not be easy to say how far these additional charges counterbalance the before-mentioned gains. One broad fact, however, seems unquestioned—viz., that, on

the whole, steam-ships are more profitable investments than sailing-ships, and are still gaining on the old class, even for the most distant services. May it not be fairly inferred, then, that the additional expenses incurred in building and working steamers do not entirely swallow up their additional earnings during their after-service? And may not this indicate that the generally-received opinion, that the space occupied by machinery is not commercially remunerative, is at least open to doubt?

Register tonnage is the legal mode of measurement for all British merchant shipping and when once ascertained for any vessel, it is cut-in on one of the main beams, or otherwise permanently marked in some prominent place. Merchants and ship-owners make common use, however, of another unit of measurement, which may be alluded to in passing—viz., the "freight-ton," or unit of "measurement-cargo," which is also used in connection with Admiralty store-ships and yard craft. This simply amounts to 40 cubic ft. of the internal space available for cargo; and so the freight tonnage can readily be found from the register tonnage. For this purpose, Mr. Moorsom gives the following simple rule:

"To ascertain approximately, for an average length of voyage, the measurement cargo, at 40 ft. to the ton, which a ship can carry . . . multiply the number of register tons contained under her tonnage deck . . . by the factor $1\frac{7}{8}$, and the product will be the approximate measurement cargo required."

This factor, $1\frac{7}{8}$, is so chosen as to allow for provisions, stores, etc., but it does not allow for passenger space, which must be separately deducted. This freight-ton is, of course, a purely arbitrary measure; but it has a definite meaning, and is of considerable service in the stowage of ships.

Some persons entirely disapprove of the employment of any system of measurement by internal capacity, on the ground that it introduces unnecessary confusion into the use of the terms "ton" and "tonnage;" as an alternative, they advocate the adoption of so-called "dead-weight" measurement—that is to say, would express the tonnage of a ship by the number of tons-weight of cargo carried. Such a scheme admits of being applied in either of two ways: first, to fix the maximum load draught line, beyond which the vessel is not to be immersed, and then to estimate the displacement, in tons avoirdupois, between this line and the light draught line, at which the vessel floats, when she has no cargo on board; second, to allow the tonnage to vary according to the amount of cargo embarked, estimating its weight by means of an officially guaranteed curve of displacement for each ship, on which the light draught-line should be marked, and the actual draught at any time could be set off readily. These suggestions have the recommendation of great apparent simplicity, but are open to many serious objections. For example, their adoption would entirely revolutionize the nominal aggregate tonnage of the British mercantile marine; and this would be no small evil, as is proved by the fact that all previous changes in the law have been intentionally so made as to leave the aggregate tonnage unchanged, the arbitrary divisors being so chosen as to give this result very nearly. As to the second mode of using this dead-weight tonnage, little need be said. There are obvious objections to having a *varying* tonnage for every ship, and it would open the way to possible evasions and disputes. Nor is the first mode more likely to commend itself, for it necessitates, first of all, the *fixing* of the loadline for each ship, and thus opens up a wide field for discussion, embracing the disputed question of freeboard in its relation to breadth and depth, as well as interfering with the freedom of private enterprise to an extent which has never yet been sanctioned. On the whole, therefore, it seems preferable to continue the use of the present Register Tonnage Measurement for all merchant shipping; the internal capacity being a fixed and ascertainable quantity, regulating the amount of cargo that can ordinarily be stowed, and governing the stowage far more, under most circumstances, than anything besides. At the same time, as was said above, there is room for further improvement in the determination of the assessable tonnage of steamers, and the subject should receive prompt attention.

War-ships differ from merchant-ships in one most important feature, which has a great influence upon the determination of the system of measurement which can be fairly applied to them—viz., that they are designed to carry certain maximum weights, and to float under those circumstances at a fixed draught, while merchant

ships have no corresponding load-line fixed as a maximum during the progress of the design. Persons who recommend that, in designing merchant ships, the maximum draught should be fixed and the load-line marked on the ship, forget that, under the very various conditions of stowage to which the vessel might be afterwards subjected, cases might occur where she might be unsafe even at a lighter draught than the designer had fixed upon, or might be safe at a deeper line. But in a war-ship the deep load-line can be, and must be, determined at an early stage of the design, in order that the height of guns above water, the draught and trim, may be secured by the detailed arrangements afterwards made. Hence for any given war-ship, the load-displacement is a fixed quantity, and can be fairly used as a measure of size and means of comparison. This load-displacement, equalling the total weight of the ship and all she carries, equals also the weight of the volume of water required to fill the space occupied by the immersed part of the ship when floating at rest in still water. It, and it only, furnishes a fair means of comparison between vastly different types of war-ships. Register tonnage is here inapplicable, for it would give little or no idea of the relative size of, say, a frigate and a monitor; and it would be of little service to compare the volumes of their internal capacity, seeing that in ships of war, especially in armored ships, the weights carried are so greatly concentrated either upon the decks, the sides, or in compartments of the hold. In short, war-ship design, while not independent of considerations of the internal space, is far more dependent upon considerations of buoyancy.

The vital question is rather, can the weights be carried on the displacement, than can room be found to stow them? The problem to be solved by the designer is, having given the displacement, to produce the best possible structural arrangements so as to associate a minimum weight of hull with the necessary strength and safety, and to obtain the largest possible percentage of the displacement for distribution in the offensive and defensive powers, the propelling apparatus and the general equipment of the vessel, in order to make her a thoroughly efficient fighting machine.

The mere statement of the displacement, of course, affords no means of ascertaining the degree of efficiency attained; that requires further and careful investigation, respecting which nothing can now be said. All that the displacement represents is the *sum total* of the weights of ship and lading, and in the determination of the relative proportions of the different items in that sum the skill of the designer is manifested.

This mode of measurement has long been in use for the war-ships of France and other European countries. It has long been recommended for adoption instead of the Builders' Old Measurement, retained until quite recently as the exclusive tonnage measurement in our "Navy List," and has at length been adopted. The change, although tardy, cannot fail to be beneficial, and we trust will speedily result in the entire disappearance of the absurd and meaningless builders' measurement. The Constructive Department at the Admiralty will, in future, be able to work more freely, and to choose proportions such as commend themselves as the best under the circumstances of each case, without having to fear the misconception of persons who, ignorant of the defects of the old rule, and looking only at its numerical results, were liable to the mistake that the builders' tonnage was a fair means of comparison between different ships.

Summing up the preceding description, it will be found that there are at present four different units of tonnage measurement in use.

I. The Ton of Builders' Old Measurement, an arbitrary measure having no definite or intelligible meaning.

II. The Ton of Register tonnage, equivalent to 100 cubic feet of the space available for the stowage of cargo and passenger accommodation in merchant ships.

III. The Ton of Freightage or Measurement cargoes, equivalent to 40 cubic feet of the cargo space of a ship.

IV. The Ton (avoirdupois weight) of Displacement, equivalent to 35 cubic feet of the volume of sea water displaced by the ship when floating at rest.

All, except the first, are useful and intelligible measures, and are not likely to fall out of use; but the builders' measurement is not merely useless, but mischievous, and cannot be too soon abolished.

# SAFETY VALVES AND STEAM IN MOTION.

By J. McFARLANE GRAY, Mem. Inst. M. E. and N. A.

From the "Nautical Magazine."

Manufacturing engineers are under the impression that it is a Board of Trade regulation that the area of the locked up safety valve shall be not less than half a square inch for each square foot of fire-grate. The only regulation with reference to area of valve is the clause in the Merchant Shipping Act, requiring that, "if such valve is in addition to the ordinary valve, it shall be so constructed as to have an area not less, and a pressure not greater, than the area of and pressure on that valve." Beyond this the surveyor is quite unhampered in his consideration of the sufficiency of area of valve, and of its general fitness for the purpose for which it is intended. The object of having the pressure not greater than on the other valve, is that the lock up valve may be the first to open, and so by its frequent action the engineer may know whether it is in working order. This regulation was more necessary before than it is now; at first lock up valves were so put out of the control of the engineer, that he could neither turn them nor "ease" them when steam was up. "To be out of the control of the engineer" is now very properly interpreted to be in every respect, except overloading, quite under the engineer's control, to turn them about on their seat, or to lift them by hand as required.

The Act indicates the minimum of area of the valve as that which manufacturers had found to be sufficient for the purpose. It was to be not less than the ordinary valve; a common rule was half an inch of valve area to a foot fire-grate, and the Board did not make a rule to hamper a changing industry, but they permitted their surveyors to approve of what the manufacturers had themselves found to be satisfactory.

For steamers large safety valves for high pressures, and loaded with weights, are open to several objections. First, when the vessel rolls, the valve spindle is inclined, and the effective load is reduced just in the proportion that the vertical height of the inclined spindle is less than its height when upright. If the pressure of steam carried is near to the loaded pressure, there is a wasteful loss of steam when the vessel is lying over.

Second, when the vessel is pitching, the effective loading of valve is increased when that part of the vessel containing the boiler is describing the lower half of its pitching movement, and it is diminished while the upper half of that movement is being described. Place a weight on the palm of your hand, raise and lower it, and you will perceive the difference of load. And so does the steam, for the rising and falling of the vessel changes the safety valve into a pump, again wastefully discharging steam into the atmosphere.

Thirdly, it is difficult to keep a safety valve in good order when there is half a ton of weights on it. The valve must necessarily be free in its seat, and every roll the weights move the valve a little to that side, and then back to the other side, wearing the face unequally.

Fourthly, the half ton of weights piled on the top of the safety valve in a locked up casing, sometimes necessarily in a not very accessible corner, renders inspection difficult, and "touching up" often unsatisfactory.

These drawbacks have been felt from the first, but while the pressures were only about 15 lbs. per sq. in., they were borne without much complaining. Pressures are now getting on to the 100 lbs., and with increasing pressure these inconveniences have grown to be serious evils.

The remedy for the safety valve difficulty has been sought in five directions.

First. The number of safety valves has been in some cases reduced, it having been found that keeping one valve in order is less expense than maintaining two of half the area each. Even in passenger steamers now, sometimes a large single boiler, carrying high pressure, has only one safety valve.

Second. Instead of having an ordinary in addition to the lock up valve, the required area of valve for each boiler has been put into two lock up valves, but so constructed that they can be "eased" or lifted, only not loaded when steam is up.

Third. The prescribed total amount of valve area has been called in question, as being unnecessarily large for high pressures, it being admitted that steam of high pres-

sure will escape through the same opening faster than steam of a lower pressure.

Fourth. Instead of direct loading, indirect by lever and smaller weight has been introduced.

Fifth. The Board of Trade have been asked to allow springs to be substituted for the dead weights in the loading of locked up safety valves.

I will dispose of the first and second of these plans by saying that I consider the first as hazardous, and the second as quite justifiable. My present object is to deal with the third, fourth, and fifth of these proposed remedies. I purpose, as far as I can, to thoroughly discuss the subject in all its aspects, and for the first time, I believe, to expose the behavior of escaping steam. I will endeavor to write what I have to say in sentences, or to exhibit it in diagrams, instead of condensing it into formulæ. But some parts of the subject can be explained only by the use of the higher mathematics; I will do what I can to put these in their simplest form, and should any reader, really anxious to follow me, come to a dead lock, if he writes to me I will try to remove the obstacle.

### THE AREA OF SAFETY VALVES.

The manufacturers' rule at present is half an inch to 1 ft. of fire-grate. What relation is there between that and the physical requirements of the case?

Evidently the first step brings us to this, that half an inch of area of valve has to give free escape to all the steam that can be raised from the consumption on 1 sq. ft. of fire-grate. What is that consumption? For our purpose I will take a high, but not uncommon rate of consumption, 24 lbs. of coal per hour per sq. ft. of fire-grate. For the steam raised, say 10 lbs. of steam per pound of coal. This might be too high were we dealing with probable efficiency of fuel as steam in the engine, but in our case we have to deduct no losses.

We have then 240 lbs. of steam per hour to pass through a half-inch area of valve. But we will find it more manageable to deal with one second only, and that will be $\frac{240}{3600} = \frac{1}{15}$ of a pound of steam per sq. ft. per second, or 4 lbs. per minute. (In round numbers we may remember that from each foot of fire-grate there can be raised one oz. of steam per second.)

We know then how fast we can make the steam; we must find out now how fast we can get rid of it. I have further on deduced from Joule's equivalent the formulæ I must now use. The first is, that the weight of common dry steam that will pass through an opening one square inch area is when the steam is above 11 lbs. pressure, $W = \frac{P.9705}{60.946}$. For steam of 100 lbs. pressure above zero this gives $W = \frac{P}{69.815}$.

For 50 lbs. it gives a divisor 68.40, and for 200 lbs. pressure it gives 71.256. Or say for any pressure above 26 lbs., that is 11 lbs. above the atmosphere, the weight of steam escaping per sq. in. of opening per second is $\frac{1}{70}$ of the gross pressure of the steam in boiler in pounds per sq. in. This divisor has been also arrived at by Professor Rankine as a deduction from an independent investigation. For the true principles of the escape of steam we are indebted to Mr. R. D. Napier's experiments, which I will discuss in detail in my treatment of this subject.

Steam of 55 lbs. by gauge is 55+15=70 lbs. pressure above zero, and as it is always the total pressure which has to be dealt with in discussing the properties of steam, we find that from this pressure 1 lb. of steam per second

$$\left(W = \frac{P}{70} = \frac{55+15}{70} = 1\right)$$

will pass through an opening of 1 in. area in one second. Through the half-inch allowed per foot of fire-grate there will escape $\frac{P}{170}$ per second. If the steam be 55 lbs. by gauge, that will be half a pound of steam per second. But for every half inch of valve there is only 1 ft. of fire-grate, and only $\frac{1}{15}$ of a pound of steam per second. The half-inch opening is therefore not required, and most certainly will never be used; the valve will, in this case, never open further than to $\frac{2}{15}$ of the prescribed area. For a general expression we have this: The proportion of full area to which the valve will open to allow all the steam to escape will be

$$= \frac{\text{The steam raised per second per foot}}{\text{The steam escaping per second per half-inch}} = \frac{1}{15} \div \frac{P}{104} = \frac{9\frac{1}{2}}{P}.$$

For steam 78 lbs. by gauge we have the area of opening

$$= \frac{9\frac{1}{2}}{78+15} = \frac{1}{10}\text{th}$$

of the area of the valve, and for steam 32 lbs.

by gauge we have the area of opening

$$= \frac{9\frac{1}{2}}{32 + 15} = \frac{1}{5}\text{th}$$

of the area of valve. When a valve opens (not *lifts*, but *opens*) one-fourth of its diameter the area of opening is equal to the area of valve. This happens because the area of a circle is the circumference multiplied by half the radius, which is, of course, equivalent to an opening all round the circumference, and of a breadth equal to one-fourth of the diameter. Our expression $\frac{9\frac{1}{2}}{P}$ is a fraction, say one-fifth or one-tenth. If then we multiply $\frac{D}{4}$ by this fraction, we will get the breadth of opening really necessary to allow the steam to escape. It will be

$$\frac{D}{4} \times \frac{9\frac{1}{2}}{P} = \frac{2\frac{1}{2}\,D}{P}.$$

This is *opening*, not lift. Safety valves are generally made with conical bearing surfaces bevelled to 45 deg.; for these the lift is to the opening as *ten* to *seven*, therefore

$$\frac{2\frac{1}{2}\,D}{P} \times \frac{10}{7} = \frac{10\,D}{3\,P}$$

is the lift required. For example, a valve 3 in. diameter for steam 85 lbs. by gauge would have to lift

$$\frac{10}{3} \times \frac{3 \text{ in.}}{85 + 15} = \frac{10}{100} = \text{one-tenth of an inch}$$

to allow the steam to escape as fast as it could be produced. Of course I mean that the valve has one half-inch of area for each square foot of fire-grate.

This seems to be a very small lift, and it is this fact which has led to the proposal to reduce the area allowed, and to use a greater range of lift.

Safety valves are intended not only to allow the steam to escape as fast as it is made, but to do so without allowing of any material increase of the pressure in the boiler beyond that for which the valve is loaded. It is evident that to lift the valve at all, the internal pressure must exceed the pressure of load. To what extent will that excess reach when the safety valve has opened $\frac{2\frac{1}{2}\,D}{P}$ or if conical has lifted $\frac{10\,D}{3\,P}$?

This lift is that required under the most favorable conditions, with perfectly dry steam, and with the best form of outlet.

It may be thought I am here a special pleader for small valves. I am stating the case as I find it, I think impartially; the above are theoretical deductions, and should be reconcileable with the following, a practical result.

I this day experimented on two factory boilers, connected. Total fire-grate 26 sq. ft. area with 4 safety valves loaded by lever and weight in the common way to 51 lbs. pressure. Each valve is 3 in. diameter, and therefore the area of the valve is more than double the half-inch per foot of fire-grate, being 28 sq. in. for 26 sq. ft. of fire-grate. All the valves were in fair working order. Arranged to have good fires before the dinner hour.

| | Pressure in lbs. | |
|---|---|---|
| 1 p. m. | 48 | Engine stopped. |
| 1 h. 1 m. | 50 | Safety valves all breathing. |
| 1 " 2 " | 51½ | Valves all blowing. |
| 1 " 4 " | 55 | Valves blowing strong. |
| 1 " 5 " | 58 | Steam escaping prevents marking lift. |
| 1 " 7 " | 60 | Can hardly see gauge for steam. |

Pressure was evidently still rising fast. We then opened the furnace doors, shut the dampers, eased one of the valves, and started the engine to reduce the pressure.

| | Pressure in lbs. | |
|---|---|---|
| 1 h. 12 m. | 58 | Steam clearing away. |
| 1 " 15 " | 50 | Engine working. |

The impression made upon all present is that these boilers have not too much area of valve. Had we taken out the levers and pins and carefully cleaned, eased, and oiled the joints, the result might have been different. But the trial was a fair one, the gear was in fair ordinary working order, and the valves worked about equally. There was no blast.

## SUSPENDED RAILWAYS.

From "The Engineer."

A suspended railway may be defined as one the permanent way of which, instead of being sustained directly by the ground, is carried at some height above the natural surface of the country traversed, on points of support more or less distant from each other. The elements of such a road may be found in an inclined wire rope stretched

from the face of a precipice to the valley below, down which baskets loaded with ore are transported, as may be seen in some mining districts. In another, and in some sense more complete form, it is to be found in the tree roads of one or two of the densely wooded islands of the Indian seas. The jungle being impassable at the level of the ground, the natives cut down long trees, and support them on posts consisting of the stumps of other trees felled high up. These tree roads, we are told, in some cases run for miles from the sea-shore inland, and they are readily traversed by the natives walking in single file, although they would present considerable difficulties to a European. The principle involved appears to possess considerable merit, and some dozen schemes for suspended railways have been brought before the world both in this country and in the United States within the last few years. As is their wont, certain engineers have condemned the idea involved in no very measured terms, principally because it strikes them as impracticable; but we think suspended railways have too many features to recommend them, to justify us in dismissing them without examination.

An immense proportion of the cost of railways is due to the construction of earthworks, such as embankments, cuttings, and tunnels. Certain districts are so unfavorable, indeed, for the construction of railways as to render it impossible to make them except at a cost which would be simply ruinous. Under the most favorable circumcumstances, however, it is impossible to construct a railway by laying the sleepers directly on the natural surface of the soil. A certain amount of earthwork must be executed, and when earthwork is reduced to a minimum the railway is invariably uneven, abounding in short inclines of varying steepness. In the case of the suspended railway there are practically no earthworks whatever. In its simplest form the track consists of one rail supported on timber posts or piles driven into the ground, and cut off to such a length that, however irregular the surface of the ground may be, the line will either be quite level or laid to a regular gradient conforming to the face of the country. We may have at one point a post driven in a hollow, and consequently rising 25 ft. or 30 ft. from the surface of the soil, while within 20 yards of it at each side may be found posts rising not more than 5 ft. or 6 ft. The vertical lines in any section showing the levels of a line of railway will represent the posts very well if we turn the section upside down, the datum line then representing the level of the track. Of course it will be understood that in practice no attempt would be made to maintain a dead level. In laying the line out a maximum and minimum height of post would be determined upon. The former might be 30 ft., the latter 7 ft. These lengths would allow a clear range of 23 ft., and a line might be carried at a dead level across any country the irregularities in which did not exceed this range in height or in depth. It might be necessary to carry the works for miles up rising ground, and in this case the railway would of course, as we have said, conform to the general slope, but not one penny would be required for work and material spent in filling up hollows or cutting down little hills. The substructure of the road, instead of consisting of earth and clay and stones, would consist of stout timber posts or piles driven deep into the soil by the aid of a modified pile-driver, while the track would be to all intents and purposes as level as that of any other railway.

It is not to be supposed for a moment that a road thus made would be suitable for the conduct of heavy traffic in a well-peopled country; but such a track would be beyond question an important boon in many of our colonies. Under ordinary circumstances the line would be single and the vehicles would as a natural consequence, be suspended below the level of the wheels, which would, run on the track above. We have seen more than one ingenious scheme in this country and in the States for the use of carriages and locomotives intended to work under these conditions; and it is quite certain that no engineer would find the least difficulty in constructing single-rail rolling stock which would work with safety and efficiency. It is possible, however, that circumstances might arise which would render the adoption of something better than a single rail desirable. There would, however, be no trouble in erecting two single-rail lines side by side and, say, 3 ft. apart, and we should then have at once the very cheapest narrow-gauge road which it is possible to construct. Such a road would, of course, only be suitable for a country where timber was plentiful, and, if properly made, not an ounce of iron would be used in miles of such a track. Every possible requirement would be found on the spot. No iron rails would

be used, the continuous timbers, some 10 in. or 12 in. square, rough from the saw-mill, would well support little vehicles fitted with broad, smooth, iron wheels. The trains would in no case weigh more than a few tons, and would easily be propelled at from five to ten miles an hour by little locomotives of 2-horse or 3-horse power. It is impossible to overestimate the value of such a little line, a very few miles long, in many of our colonies, as a means of conveying produce of various kinds, such as coffee across an inaccessible tract of land to a good road, a river, railway, or the sea-side. Nor is it possible to urge with truth a single objection to such a line as regards the power of working it with ease, safety, and regularity. It may, indeed, be asserted that the line would not be as good as an ordinary railroad. This no one disputes; but when it becomes a question of a suspended railway or of no road at all, it is useless to draw such comparisons.

If the double line were adopted—and in most cases the double line would be infinitely preferable to the single line—the mode of construction would be excessively simple. It would first be necessary, of course, for an exploring party to lay out the route; but the extent of ground to be cleared by the axe men in doing this would be very small. Subsequently a greater width of jungle would have to be opened up. A saw-mill would be a necessity. This mill would be established near one end of the line, and by it the piles would be prepared. The line once begun would advance rapidly, the permanent way being laid as fast as the piles were driven. The pile engine would, of course, run on the road, advancing as it advanced, and very little trouble would be experienced in sending up the piles from the saw-mill to the front as they were required. If, as is probable, the railway led to a river, the timber for the piles would be floated down to the mill in a way well understood; but if there were any difficulty about this, it is not beyond the resources of the engineers to send up the saw-mill itself to the front, and so begin on a new basis as soon as one district was cleared of the available timber.

We do not assume that the work of making such a line would be all plain sailing, but we think that a few Yankee lumbermen, aided and directed by a couple of sharp engineers, and an efficient staff of laborers, would find very little difficulty in building eight or ten miles of such a road in three months. Of course the details of construction would vary with different circumstances, but no profound engineering problem would ever arise for solution. The cost would in any case be very small indeed; and there is no reason why a suspended railway should not be 50 miles long, if need be, as well as eight or ten. By the aid of such lines whole districts in Ceylon—to name but one country out of several—would be opened up, which, although capable of being made enormously productive, are now valueless because they are inaccessible. Of South America the same statement holds good; in a word, of the utility of suspended railways there can be no doubt. That they would cost less, *cæteris paribus*, than any other roadway possessing the same advantages is, we venture to think, equally certain. If these statements represent the truth, then we venture to think that colonial engineers cannot do better than give the merits and demerits of the suspended railway the consideration which we believe the subject deserves.

## BRIDGE CYLINDERS.

From "Engineering."

It is scarcely more than 30 years since the principle of founding the superstructure of a bridge upon hollow cylinders was carried into practical operation. It may be safely stated that, where practicable, this method of obtaining a sound and reliable foundation in the bed of a river is at once the simplest, the cheapest, and the most rapid in execution. The nature of the material of which the cylinders themselves are composed, whether of cast or wrought iron, is a matter of detail which does not affect the value of the principle. There is no question that the introduction of concrete as a constructive material, and the favor it has ever since enjoyed at the hands of engineers and architects, very considerably influenced the adoption and use of the cylindrical system of bridge foundations. So far as hollow cylinders of a small diameter are concerned,

the employment of concrete presented the only means of filling them, as their dimensions were too contracted to permit of brickwork or masonry being laid in their interior. As there is not sufficient room for men to work in them, they cannot otherwise be filled. It will be as well to have a clear idea of the proper function of a hollow cylinder and the duty it has to perform when sunk in the bed of a river. The common opinion is that it acts as a direct support for the superstructure placed upon it. This idea is generally erroneous. It seldom does anything of the kind, and in this respect differs from the action of pile foundations. The duty of a cylinder of the description we have mentioned, and in the position assigned to it, is simply that of a surrounding envelope or covering to the material inside it. The latter may consist of concrete, stone, brickwork, or, as is frequently the case, partly of one and partly of the other. It is, in fact, an iron casing sunk into the river to allow of a solid core or pier being built in its interior, which could not be erected without its protection and support. It is possible that in some instances, when the solid cores or piers are built, the superstructure erected, and the whole bridge brought to its bearings, the cylinders themselves might be removed without any danger of injuring the stability of the structure. As this removal could only be effected above the level of low water, or, at the most, above the level of the river bed, and as nothing would be gained by the operation, the rule is to leave piers as originally put together. Moreover, it is probable that when the internal filling consists of concrete, the cylinders effectually assist in retaining it in form and prevent any tendency to its spreading laterally—or squeezing out—if the term may be applied to a solid material. A glance at the character of the foundations of the majority of the most recently constructed bridges over the Thames, as well as of those in progress, is sufficient to prove the truth of our assertion with regard to the views entertained by engineers on this point.

In sinking cylinders, it is sometimes necessary to use either Hughes' or Pott's method, but the most favorable circumstances under which this system of foundations can be adopted is, when the cylinders can be got down by the combined action of excavation and weight. The two former methods are troublesome, expensive, and to some degree uncertain. The last is free from all these objections, and upon the possibility of rendering it available ought to depend, in a great measure, the selection of this principle of foundations. There can be nothing more vexatious to an engineer or harassing to a contractor than to have a number of cylinders lying ready for him while he is unable to proceed with the sinking of them. It is bad enough to be compelled to wait for materials when the working arrangements are in perfect order, but it is a great deal worse to witness the materials accumulating without being able to dispose of them. With the exception of rock and very compact gravel, there is, perhaps, no description of bottom which is not adapted for cylinders. A difficulty occurs occasionally when the substratum is sand, and in which the pressure of water is so great as to cause a "blow." But this may be successfully overcome by having recourse to a large auger or "miser," by which the excavation can be proceeded with without entailing any very serious amount of pumping. The question of pumping, and the quantity of water likely to be met with, must be taken into consideration in deciding upon the adoption of this system of foundations. Obviously, a prolonged spell of pumping, during which the downward progress of the cylinder might be little or nothing, would very much detract from the advantage of the principle in that particular case. It must be remembered that in these, and all similar operations, which are of a purely practical character, their success depends altogether upon the experience and skill of the engineer who has the responsibility of carrying them out. In addition to possessing merely a knowledge of the details of engineering and constructive works, he must be a man of resources. He must be thoroughly familiar with the management of men, and accustomed to the manipulation, both by hand and machinery, of materials in large masses in uncouth shapes, and of heavy weights. Above all, he must be a man full of contrivances, apt at meeting and overcoming unforeseen contingencies, and able to accomplish the same object in any one of half a dozen ways, which might prove the most desirable. It is in getting in the foundations of a large bridge over a river—whatever may be the system employed—that there is abundant scope for the display of these qualities so essential to a practical engineer. Very frequently the most expensive portion of a large structure

—the foundations—are always sure to be the most hazardous and troublesome, and to require more constant supervision than the remainder of the work.

There are two general processes available for sinking cylinders in a river or in the sea. The one is to erect a staging for the purpose, and the other to sink them from boats or pontoons. The principal points which would influence decision in the matter are the nature of the bed of the river, the depth of water, and the velocity and strength of the current. To these must be added the character of the river itself, whether its flow and depth of water be uniform and constant, or whether it be of the Indian type of streams, some of which can be traversed dry-shod at certain seasons, and at others possess all the violence and fury of a mountain torrent. The depth of water would not necessarily increase the difficuly of erecting scaffolding and staging, although it would undoubtedly add to the cost of them, as stronger timbers would be required for the uprights and horizontals, and a greater amount of cross bracing to give rigidity to the whole framework. A timber staging or scaffolding on a large scale is nothing more than a huge truss, and the laws which govern the correct and scientific distribution of material, and the proper arrangement of struts and ties in iron trusses, apply with some slight modifications to those of timber. If we turn our attention now to the sinking of cylinders by the aid of pontoons, it will be seen that this method is independent of two of the dangers which threaten the other. These are the depth of the water and the nature of the river bed, provided that in the latter case there is holding ground for anchorage. But, on the other hand, it is more difficult to protect it from the third danger, that is, the violence of the current. A strong staging, thoroughly well braced together, presents comparatively little resistance either to the wind or water, and is but little affected by them. The case is very different with a pair of long pontoons, which must be maintained by moorings perfectly steady at the site of the cylinder to be sunk. It is also evident that an overhead staging affords more command of the cylinders, and more freedom of action in hoisting and pitching them than pontoons. If gantries or travellers, be employed the advantage will still rest with the staging. The means used for the actual excavation of the bed of the river in the interior of the cylinders will depend upon the nature of the ground at that depth. If of a hard, tenacious character, a cutter of some kind must be used, and worked either by hand or machinery. In sinking the cylinders in the Gorai river, one of the large tributaries of the Ganges, for a bridge on the Extension of the Eastern Bengal Railway, a cutter of peculiar form was employed. It consisted of a horizontal disc-plate, furnished with four blades fixed at right angles to one another, and projecting downwards in a vertical direction from the under side of the disc. The shape of the blades was triangular, and they were provided with cutters, so that while revolving, the machine excavated a hole of a conical shape, 9 ft. in diameter. The whole apparatus was worked by a compressed air engine, with the assistance of some hand-gear. An instance in which very simple means sufficed to remove the contents from the interior of very large cylinders was afforded by the foundations of the Albert Bridge, which is now in an advanced stage of progress. It must be premised that the stuff excavated was of a different character to that existing in the case of the Gorai Bridge. The cylinder having been pitched and bedded, the excavation was carried on by the combined action of a small steam engine, a scoop, and a diver. The scoop contained about half a ton, it was adjusted under water by the diver, and worked by the steam engine, the whole operation being conducted with ease and certain. A rather curious little incident occurred in sinking the cylinder on the upstream side of the bridge on the Surrey shore. The cutting edge of the lowest ring came right across a hole that had been originally filled by a pile which had been afterwards drawn. Consequently, although the cylinder continued to sink at a fair rate, the water nevertheless continued to flow in, passing down the hole on the outside of the cylinder and up it in the inside. After some little delay and trouble, this trifling hitch was got over.

Kentledge, rails, monkeys, and, in fact, whatever tolerably heavy articles of iron can be conveniently obtained, are rendered available for weighting cylinders, and so either assisting their sinking or forcing them down when necessary. These weights are not piled on indiscriminately, as might possibly be imagined, but care is required to adjust them properly both with regard to their number and their position. It is not

advisable to sink a cylinder with too great rapidity, and the nearer the perpendicular it can be maintained throughout the whole process of sinking, the better. In this respect it partakes of the character of a column, the strength of which becomes at once diminished by any deviation of its vertical axis from the perpendicular, or by any unevenness in its bedding. If a cylinder in going down heel or cant over to any very appreciable degree it becomes liable to a cross strain, which, if permitted to increase or even continue, might ultimately cause it to crack, or, perhaps, rip right open. It is obvious that as the whole cylinder consists of several successive rings or lengths, the weights must be removed every time a new length is bolted on. Where the weights are few, which occurs when the cylinder sinks easily, the delay occasioned by this alternate removal and reimposition is not of much consequence. But when the weights, instead of merely assisting the cylinder to "go down," are required to perform the office of forcing it down, their total number and weight render the process of shifting and replacing very tedious, and involve very considerable delay. A plan was adopted at the Gorai Bridge which obviated this inconvenience. A water tank, holding when full about 90 tons of water, was made to fit on to the top of the respective rings of the cylinder. It could be filled in 10 min. by a pump, and emptied in a proportionately short time. The only point that does not appear satisfactory with respect to this plan of weighting, is that there are no means of loading on any particular part of the cylinder, and the canting of the cylinder would aggravate the evil by sending the water to the lowest end of the tank. The weight must either be uniformly distributed or not at all, whereas in sinking large cylinders it is frequently necessary to load only one-half of the circumference of a rim at a time. In fact, it is in this manner that the cylinder is maintained in a perpendicular position when inclined to heel or cant to one side. Partial weighting could be obtained by means of a water tank, provided it were divided by water-tight bulkheads into several compartments, any number of which could be separately filled at pleasure. It would be difficult to form an opinion what is the maximum depth to which a cylinder could be sunk, supposing the strata to be favorable to the operation. The land cylinders of the Gorai Bridge were sunk through 120 ft. of earth, about 40 ft. of which depth were got through by open excavation, so that the actual sinking only extended for a depth of 80 ft. Whatever may be the maximum depth, if we are to judge by the wholesale sweeping away of the piers and cylinders of the bridges in the Indian rivers, it is in that country that engineers will have the merit of discovering it, if they wish to avoid such catastrophes in future.

## LEAD MINES AND WORKS OF GERMANY.

From the "London Mining Journal."

The treatment of these ores varies according to the nature of the matrix. The English process of smelting is used in some places on the Continent, but more commonly the smelting is effected in a small blast-furnace, with an admixture of iron, to form a fusible slag. In most of the smelting works we visited in the Hartz this latter method is followed. The galena ores, dressed up to 70 per cent., are carefully mixed with slags from former operations, iron, and bottoms of old cupels, in the following proportions:—

| | |
|---|---|
| Galena, averaged at 70 per cent. lead | 37 |
| Fine sandy ore, silicious | 5 |
| Cupel bottoms, litharge | 5 |
| Pure litharge | 1 |
| Slag, to act as flux | 47 |
| Cast-iron, in fragments | 5=100 |

The furnaces are about 7 yards high, and so arranged on the floor that the furnace hearth comes level with a step in front of the brickwork, and projects some distance into this step. Here the slags forming on the top of the hearth are drawn off by the workmen at intervals, and set aside, to be subsequently added to a fresh charge of ore. A blast, worked by a water-wheel, is supplied to the hearth. The cold blast entering the furnace cools the melted matters in its path, and forms a sort of slag channel from the tuyere into the interior of the hearth. This is said to be of great importance in preventing the too rapid combustion, and in sensibly warming the air before it comes in contact with the metal. The upper part of the furnace is occupied with

several chambers, through which the fumes pass before escaping up the chimney. In this respect, however, many of the German works are inferior in arrangement to the English, not being provided to the same extent with flue accommodation to collect the oxide. The flues of the Greenside Smelting Works, in Cumberland, are three or four miles long, and on the occasion of our last visit were being lengthened out to seven miles, built, of course, on the ground. Indeed, the manager informed us that, so far as practical experience in England had gone, there was no limit to which the flues might not be remuneratively carried.

As the charge in the furnace gradually liquefies, slag forms, and cools on the upper part of the hearth, from which it is now and then removed by a hook, and put aside, the richer varieties to mix with a fresh charge, and the poorer varieties to be wheeled to the waste heap. When the hearth is seen to be full of metal it is tapped off into a basin, fixed in the floor, at the foot of each furnace, where it readily separates into two layers, the upper one a brittle mixture of ferruginous and plumbiferous sulphides, called the first matt, and the lower layer of metallic lead. The total produce from the minerals above given amounts to 26 per cent. of the charge.

In these furnaces much depends on the skill of the smelter, whose attention is constantly required in the method of charging the materials, the degree of temperature maintained, in seeing that no metallic lead escapes with the slag, and that as little metal as possible is lost by volatilization. The fuel employed is coke.

The treatment of the rich slags from off the lead baths occupies an important place in the smelting establishments; and in this respect the arrangements were generally much superior to the corresponding process in England. The slags, as before remarked, are mixed sulphides of iron and lead, with variable amounts of copper, antimony, nickel, etc. These slags are calcined in heaps, in the same manner as native sulphurets, to expel the sulphur, and then they are reduced in a smaller furnace, supplied with a moderate blast. The charge consists of equal quantities of roasted matt and slag, to which is added one-sixth their weight of a mixture of litharge, silicious slag and iron. A quantity of metal is produced from this furnace, which is run off into a basin, in the same manner as from the reducing furnace. Here it readily separates, as before, into two layers, the lower of pure lead, the upper of a slag, similar to the original slag in composition, but poorer. This is called the second matt, and is roasted and reduced in a similar fashion, producing lead and a third matt, and in the same way a fourth matt is produced. By this time the slag, by the successive withdrawals of lead, has become impoverished, until it ceases to pay; but the copper originally present in the ore, having a greater affinity for sulphur than lead has, becomes successively enriched, till in this fourth, or copper matt, as it is called, it becomes the more valuable substance, and it is for this accordingly treated. The various works at Clausthal and Goslar pursue substantially the same method. But for ores containing less than 30 per cent. of lead we found another form of furnace in use in the Eastern Hartz, which, we understand, has been recently introduced into England with great success, to smelt the more refractory ores, and the poorer slags from former workings. The furnace is round, and smaller than the ordinary lead-smelting hearth. The internal diameter is 1 metre and the height 3 metres. The body of the hearth rested generally on cast-iron pillars, but in one works, near Königsburg, we observed the hearth was supported on four brick pillars. The body of the hearth is filled with coke dust and charcoal, well beaten down, so as to form the floor, and a good blast is supplied by three or four tuyeres. The slag formed is very fusible, and this method is said to yield very good results, quite equal to assay. Galenas and slags containing not more than 7 or 8 per cent. are worked to a profit by this method. The fuel is coke, each ton of the poor ore requiring 2 to 3 cwt. of fuel. Owing to the higher temperature, long flues are of more importance in this than in the ordinary reducing furnace. The flues at Königsburg, where this method is followed, were tolerably extensive, but in our opinion might be profitably extended. The manager, however, thought it would not pay.

The lead ingots so obtained throughout the Hartz are next treated for silver. The average richness in the Clausthal works being 106 oz. to the ton. The refineries are usually in a separate building, and the operation is conducted in three different ways. In one works Patinson's process was in operation, in which the silver-lead is allowed to crystallize slowly in iron vessels, where,

as the pure lead crystallizes first, and is constantly removed by a perforated ladle, the mother liquor continually enriches in silver, until it is several thousand ounces to the ton, and is then cupelled, in the manner described in our last article on silver. The second method we saw at Frederickshütte, where the argentiferous lead is melted in a large cast-iron vessel, while a smaller one stands near, containing zinc in a state of fusion. The metals are then mixed in the proportions of $1\frac{3}{4}$ lbs. of zinc to 1 oz. of silver in the alloy. This mixture is now kept at a melting heat, with constant stirring, for two hours, then allowed to stand. A scum forms on its surface, which contains the zinc and silver, and is constantly removed as it forms. When this scum no longer rises the liquid lead is run off, and exposed for some time to a red heat, to drive off the last traces of zinc in vapor. The lead is next kept in a state of fusion for two hours, with the addition of a billet of green wood, the exact purpose of which we could not ascertain from the smelters, but it seemed to purify the lead and improve the quality. The matters skimmed off are next re-melted in a sloping tube, from which the metallic lead flows as it melts, and is at once cupelled for silver; while the zinc residue is distilled in retorts, with the addition of coal dust, according to the method commonly adopted for zinc, and about 50 per cent. of the quantity originally employed is obtained. An obstinate residue of zinc and silver remains in the retorts. To this a fresh quantity of lead is added, which, when melted, alloys with the silver, and is then obtained by cupellation in the ordinary fashion. The lead appears to be more thoroughly freed from silver by this method, and where the proportion of silver is small—say, 20 oz. to the ton—there is no doubt it will be advantageous. The manager at the works spoke highly of the economy of this process, as did also the students at the Clausthal School of Mines, but we believe it is not much practised in this country.

The third method is that of direct cupellation, which is only used in the case of very rich ores, and even then it does not seem to be by any means economical, and is much less used now than formerly.

In the next article we purpose to describe our visit to Wilhelmsschact, one of the largest collieries in Saxony.

## THE MACHINERY OF SHIPS OF WAR.

From "Naval Science."

The extent and variety of the mechanical arrangements in our ships of war will be familiar to most of our readers. Nothing excites the wonder of the visitor to one of our turret ships, for example, more than the apparently chaotic jumble of engines, wheels, pipes, cranks, etc., by which he is surrounded, and even the experienced engineer in charge, who is supposed as a part of his duty to have mastered the intricacies of this labyrinth of mechanism, becomes occasionally bewildered in attempting to distinguish between pump gear and turret gear, steam gear and hand gear, etc. Not only, however, can a good reason be given for the presence in the ship of every part of this mass of machinery, but the inevitable tendency is to add to its complexity. The increasing weight of the guns mounted on shipboard, and also the increasing danger of a want of celerity in the movements of the ship, render it extremely probable that the use of manual labor will be dispensed with to a far greater extent than at present, and that the power stored up within the iron walls will be made still further available for the rapid manipulation of the ship and her ponderous ordnance. With the auxiliary steam power for steering, working guns, capstans, etc., we do not, however, intend to deal. It is to the consideration of the design and arrangement of the "main" or propelling machinery as affected by modern conditions of naval warfare we propose to devote this article.

It is not within our purpose here to discuss questions relating to the probable development of the art of attack and its general effect upon the construction of ships of war, but the following appear to us to be fair conclusions to be drawn from a careful study of these questions so far as they immediately affect the arrangement of the machinery.

First, with regard to armor-clad ships. If naval warfare were to be confined to a mere conflict of the heaviest guns that

could be mounted afloat, the attainment of high speed in an iron-clad might well be sacrificed for the purpose of enabling a greater weight of guns or of defensive armor to be carried. Attacks by ramming and by the moving torpedo have, however, introduced formidable dangers to which slow and unwieldy ships will be peculiarly liable; and we may therefore regard the attainment of high speed in order to secure the greatest possible mobility in action, even if for no other reason, as one of the first objects to be aimed at in the design of ships intended to fight at close quarters. Also, in an action at close quarters, the temporary disablement of the propelling machinery would in all probability place a ship, despite her gun power, at the mercy of an enemy provided with either ram or torpedo, and as injury from both these modes of attack is received below the water-line, the additional protection from shot or shell given to the machinery by placing it below the water level does not appear to be of sufficient importance to counterbalance the disadvantages attending its arrangement in this way. One serious disadvantage is the difficulty it places in the way of a subdivision of the compartments, which, so far as that portion of the ship occupied by the machinery is concerned, would give the nearest practicable approach to the "cellular construction" recommended by the Committee on Designs.

Next, with reference to unarmored ships. The most important class of vessels of this description which it has been the recent policy of our own Government to build, is one intended for the protection of our commerce, and high speed has been sought in this case with the object of enabling the vessel either to overtake, and fight if necessary, an unarmored enemy, or to escape from an armored one. It is imperative here that the machinery should be kept as far as possible below the water-line, and although the ship would rarely be exposed to under-water attack, as she would seldom come to close quarters with an armed enemy, the subdivision of the machinery compartments appears to be quite as essential as in the case of armored ships, in view of the destructive effects of modern shells against unprotected vessels.

Whether the ship be an armored or an unarmored one, it appears to be evident that, with regard to the design of the machinery of the more important vessels, we require, in order to meet the exigencies of modern naval warfare, to favor the following features:

1st. Great range of power, coupled, as a matter of course, with economy of fuel at all speeds.

2d. The greatest attainable security from even temporary disablement in action.

3d. Facility for rapid repair and disconnection of disabled parts.

With most modern engines, whether compound or simple, the maximum power which can be developed is dependent on the boiler. We are aware that compound engines are being made in which the steam is intended under ordinary working conditions to be carried for nearly, if not quite, the whole length of the stroke in the high-pressure cylinder; but these are manifestly unsuited for ships of war, and, we may also remark, are at variance with some of the theories of engineers who advocate the inherent superiority of the compound over the simple form of engine so far as the action of the steam in the cylinder is concerned. With the compound engine, even in its best form, however, the range of power (as dependent on the cylinders) is not so great as with the ordinary expansive engine; but in either case the practical limit of the power of the engine is determined by the steam-producing capabilities of the boiler, and here we find that the type of boiler which is now being substituted for the "box" or rectangular boiler on shipboard, is not well adapted for the development of great power on an emergency.

The various forms of the "box" boiler are rapidly becoming obsolete for marine purposes generally, as the use of the surface condenser has enabled steam of higher pressure to be used on shipboard. These boilers are easily stowed, and in most cases ample steam room can be obtained with them, while the wall-sided furnaces and roomy combustion chambers are well adapted for rapid and economical combustion of the fuel. The great extent of the flat surfaces requiring to be stayed prevents their adoption, however, for steam of more than about 30 lbs. pressure, and in lieu of them cylindrical and oval boilers are now in general use. In these the arrangement of the tubes is similar to that of the "box" boiler, and combustion chambers of good capacity can be given; but the cylindrical furnaces which are fitted are not at all suit-

ed for carrying heavy fires, and the maximum rate of combustion of the fuel per square foot of grate is considerably less than with the older type. Though requiring a greater amount of staying than the cylindrical boiler, the oval form of high-pressure boiler is more easily stowed, and advantage can be taken of the full depth of the hold to give good steam room without making a shell of objectionable dimensions. Either boiler can, however, be made easily accessible for cleaning, examination, and repairs, and (with steam of what has now become the ordinary working pressure), notwithstanding the disadvantages attending the use of the cylindrical furnaces, they are probably the most trustworthy boilers that can be adopted for ships of war, and more especially so for armored ships, as they are here protected in a great measure from projectiles.

In unarmored ships, however, the exposure to the direct effect of projectiles of large boilers containing great quantities of hot water and steam at a pressure of 60 or 80 lbs. to the square inch becomes a serious matter, and it is therefore most important that a form of boiler not liable to extensive or permanent injury, when struck by projectiles, should be provided for this service. One feasible way of meeting the difficulty would be to adopt a boiler built up entirely of tubes.

This description of boiler has been used on land in many forms with more or less success for a number of years, and it is now being introduced to some extent on shipboard. The construction for marine purposes of a satisfactory boiler of the "tubulous" type, as it has been named, is a wide and intricate question, and we do not here propose to discuss the relative merits of the various modes in which a solution of the problem has been attempted. It appears to us, however, that boilers built up of tubes are peculiarly adapted for use in ships of war. The explosion of shooting away of a few of the tubes could not possibly be attended by results so disastrous as would be sure to follow the explosion of an ordinary boiler. There seems to be nothing to prevent the adoption of furnaces capable of giving a high rate of combustion, and the great comparative safety of the boiler in an action would give increased confidence to the stokers and engineers, whose post—in unarmored ships more especially—in front of large vessels charged with high-pressure steam, and liable at any moment to be perforated by some projectile, is, to our mind, the most unenviable in the ship. With a form of furnace favorable to rapid and complete combustion, the great extent of space taken up by the ordinary type of boiler could be materially reduced.

In connection with the boilers the provision of a copious draught to the furnaces is one of the most important questions to be dealt with in arranging the machinery. Efficient ventilation of the stokeholds, combined with a free use of the blast-pipe, when it is required to force the fires, appears to find most favor in our own Navy—and this plan, while possessing the great merit of simplicity, gives sufficient control of the supply of air to render the power of the engine practically dependent—with a good form of furnace and boiler—on the quality of the fuel, and upon the skill and endurance of the stokers. Systems of fans for the supply of air to the furnaces, by either exhausting up the funnel, or forcing the air directly into the furnace, have frequently been proposed, and have formed the subject of patents in this country. They have also been used to some extent in the American Navy. There is much to be said in favor of arrangements of this description, both in point of economy of fuel and control of the evaporative power of the boiler, and they are worthy of serious attention from the fact that by contributing to increased rapidity of combustion their adoption would tend to lessen the boiler space, and give greater room for the capacious cylinders required in order to realize the full benefits to be obtained by the use of high-pressure steam, for the carrying of which the "tubulous" boiler is specially adapted.

The choice of the type of engine best suited for ships of war involves a number of questions, to the minute consideration of which we shall not be able to devote present attention. We think it may safely be assumed, without discussion, that the proved economy attending the use of high-pressure steam has rendered imperative the adoption of engines working at a pressure of at least 60 lbs. for all the more important ships. Whether steam of this pressure can be used as efficiently in an ordinary expansive engine as in a well-designed compound engine is a question which has been much discussed of late, and many interesting articles on the subject in the leading

engineering journals will, no doubt, be familiar to our professional readers.

In discussing the relative merits of the rival types, it is palpably misleading to institute comparisons between an engine of one type working at 15 or 30 lbs. pressure and that of another working at 45 or 60. No doubt this has frequently been done from want of other data, for until recently no ordinary engine working at 60 lbs. pressure with great capacity for expansion had been tried in the navy, and trustworthy information on the subject from other sources has not been available. The results of the most recent experiments we give further on, and we may remark here that it is a significant fact that the compound engine could not compete successfully with the ordinary type in the Navy until worked with steam of about double the pressure of that used with the simple engine.

With regard to the theoretical aspect of the question, a better authority could scarcely be quoted than Professor Rankine, probably the greatest living authority on the science of Thermodynamics in its application to the steam engine. In a Report to the Committee on Designs, which may fairly be taken to represent his matured opinions upon a subject to which he has devoted much attention, Prof. Rankine advocates the superiority of the compound engine, but upon grounds to which we think experienced marine engineers are not likely to attach much importance, He writes: "So far as the theoretical action of the steam in the cylinder is concerned, it is immaterial whether the expansion takes place in one cylinder or in two or more successive cylinders. *The advantage of employing the compound engine is connected with those causes which make the actual indicated work of steam fall short of its theoretical amount;* and also with the strength of the engine and its framing, the steadiness of its action, and the friction of its mechanism.

The sentence we have italicized here is very vague; but we find the Professor, in comparing the performance of the six-cylindered compound engines of the Constance with those of the Octavia and Arethusa (ordinary engines), expressing his opinion very explicitly as follows: "The superior economy of fuel as compared with *indicated power* in the Constance is of course to be accounted for by a higher initial pressure and a greater rate of expansion than those used in the other vessels, combined possibly with better jacketing and greater superheating."

So far as the action of the steam was concerned, a question upon which he is eminently qualified to express an opinion, Professor Rankine here distinctly attributes the superiority of the compound engine, in the case of the Constance, to arrangements which we need scarcely say are quite applicable to ordinary engines.

He goes on to say: "But the superiority of the Constance over the Octavia in efficiency of mechanism—in other words, in economy of indicated power as compared with effective power—can be accounted for only by the comparative smallness of friction in the engines of the Constance, and when it is considered that the engines of the Octavia were of good design, and of the best possible workmanship, the comparative smallness of the friction in the Constance must be ascribed mainly, if not wholly, to the balance of driving forces, the result of the arrangement of opposite cranks in Mr. Elder's three-cylindered compound engines."

Mr. Wright, the experienced Engineer-in-Chief to the Admiralty, has, in his evidence before the Committee, pointed out the untrustworthy character of the data upon which Professor Rankine has endeavored to establish the superiority of the Constance in point of efficiency of mechanism, stating that with regard to the apparent difference between the ships in this respect he "should be rather inclined to ascribe it to the difficulty of ascertaining the indicated power with sufficient accuracy to form a conclusion upon the subject."

But even assuming that the indicated power had been correctly given, and that an actual difference in favor of the Constance during the trials could be established, we think few engineers of experience, with a knowledge of the facts, would have ascribed this superiority of performance to the "smallness of friction" due to a complex arrangement of six cylinders. It is pretty well known in the marine engineering world that the engines of the Constance were not regarded as a success in point of facility of handling, the popular idea being that their defects in this respect were mainly due to excess of friction; and we should not, for our own part, be surprised to find that a report to the effect that the engines occasionally required strong persuasion in the shape of powerful jacks to induce them to start is true, notwithstanding the "balance of driv-

ing forces." We venture to think that if Professor Rankine had in his investigations given greater prominence to other differences in the two ships than those to which he refers, he would scarcely have committed himself to an expression of opinion which is little likely to secure the respect usually accorded to the results of his labors in the many fields of scientific inquiry to which he has so successfully devoted himself. As pointed out in an interesting article on this question in the "Engineer," the engines of the Octavia having three cylinders with cranks disposed at angles of 120 deg., would compare favorably with those of the Constance so far as a balance of driving forces was concerned; and we believe an explanation of the superiority of the Constance in point of efficiency of mechanism, presuming that it existed at all, would be found in the difference of pitch of the screws and the velocity of the piston.

The compound engines which have been found to be the most successful in the Navy are those of the two-cylinder type, with cranks at right angles, as fitted in the Briton, Tenedos, etc. A very instructive trial was recently made with an engine of this type in competition with an ordinary twin cylinder engine, working at the same boiler pressure, and fitted to cut off the steam at a very early portion of the stroke. The results of the trials have already been published in the engineering journals, but we reprint them here for the information of our readers, as being the most recent and trustworthy upon the question we are discussing.

| | Goshawk. (compound.) | Swinger. (not compound.) |
|---|---|---|
| Diameter of cylinders | {High pressure 28 ins. / Low pressure 48 ins.} | ..... 34 ins. |
| Stroke | 18 ins. | ..... 22 ins. |
| Indicated power developed | 374.7 H.P. | 363.86 H.P. |
| Pressure of steam in boilers | 60 lbs. | 60 lbs. |
| Mean pressure in cylinders | {High pressure 30.69 lbs. / Low pressure 7.65 lbs.} | 15.59 lbs. |
| Revolutions per minute | 126.08 | 115.68 |
| Piston speed in feet per minute | 378.24 | 424.16 |
| Vacuum in condensers | 25.45 ins. | 26.02 ins. |
| Quantity of coal consumed | 5,852 lbs. | 5,700 lbs. |
| Coal consumed per I. H. P. per hour | 2.6 lbs. | 2.61 lbs. |

Calculating from these data, it will be found that the volume swept by the piston per indicated horse-power was 17 cubic ft. in the Goshawk against 14.7 only in the Swinger. The way in which the "six hours runs" are conducted in the Navy is admittedly faulty with regard to the manner in which the consumption of fuel is ascertained, but the mode of trial was of course equally fair for both ships, and we have no doubt the trials were conducted in exactly the same way as those upon which the reputation of the compound engine has been established in the Navy. Without, however, regarding the results obtained as conclusive, we think it a most suggestive fact that the simple engine in this case, with a much less capacity for expansion, should have been found to work with practically the same consumption of fuel as a compound engine of the most approved type.

As an engine peculiarly adapted for high-pressure steam, we regard the general introduction of the compound engine in the merchant and mail services, and in special service ships attached to our Navy, as only a question of time; but that any advantage would be gained by its exclusive adoption for our ships of war, as strongly recommended by the Committee on Designs, appears to us to be very doubtful. Beyond the single fact of its proved economy in the consumption of fuel, it has nothing to recommend it for modern ships of war, and we think our readers will allow that there is a fair prospect of equally good results in this respect being obtained with simple engines, at what has now become the ordinary working pressure. The inter-dependence of the cylinders of the compound engine renders it extremely liable to total disablement in an action, and the dissimilarity of the spare gear, owing to the difference in dimensions of the cylinders, slide-valves, etc., together with the comparatively unmanageable size of some of the principal parts, presents serious obstacles to rapid repair.

We may here remark, however, that the objection of great weight frequently urged against the compound engine of the most modern design is mainly due to the high pressure of the steam used, and the great range of expansion, and not to the type of engine. There is little doubt but that the same capacity for expansion must be given to a simple engine if a similar result in point of economy of fuel is to be expected, and as the maximum strains upon the mechanism are far less in the compound than in the ordinary engine, the quantity of metal required to resist the strains is of course proportionately less. Taking into consideration the reservoirs and the additional spare gear—no inconsiderable item—required with the compound engine, we should not expect much difference between the weights of well-designed engines of the two types working at 60 lbs. pressure when the same capacity for expansion is given.

Notwithstanding the recommendation of the Committee, the Admiralty appears to be wisely inclined to give both forms of engine a fair trial (so far with the result we have already stated), and we have no doubt the question will be well weighed by the able chiefs of the Comptroller's Department.

The extensive division of the hull of the ship into water-tight compartments, which appears to be the most feasible method of guarding against the effects of under-water attack, seriously affects the arrangement of the machinery. When it is considered that in most cases about two-thirds of the submerged area of the skin of the ship exposed to attack covers the engine and boiler compartments, containing a delicate system of mechanism upon whose sustained efficiency in action the very life of the ship depends under the modern conditions of naval warfare, it will be seen how important it is that these compartments should be extensively subdivided, with the object of preventing, if possible, the disablement of the means of propulsion.

So far as the boiler compartments are concerned, there can be no great difficulty in this respect with any of the ordinary forms of boiler, and we think the "tubulous" type would not only offer further facilities for the subdivison of the compartments, but, as already pointed out, a better form of furnace could probably be obtained, and if combined with a forced draught, a considerable reduction in the boiler space might be expected.

In ships where the protection given by the armor admits of part of the engines being brought above the water-line, vertical or inclined engines can generally be introduced, and these readily admit of protecting water-tight compartments being provided. Twin screws still further facilitate the subdivision, and, with the engines vertical, give a short engine-room, a thing otherwise very difficult of attainment on account of the great capacity of cylinder required with the modern high-pressure expansive engine. The difficulties from this source are probably greatest in unarmored vessels where great power is required with a single screw, and we can easily understand the objection of the professional advisers of the Admiralty to adopting compound engines for the Blonde on the score of the size of cylinder required alone. This ship is an unarmored frigate of the Inconstant class, with a single screw, and according to evidence given before the Committee on Designs her horse-power is to be 7,500 indicated. In order to bring them below the water-line the engines must be horizontal, and to give the same capacity for expansion as the Goshawk's, for example, the cylinders would require to be of impracticable dimensions if the engine were made with two cylinders only. Taking the speed of piston at 600 ft. per min., and the volume swept per indicated horse-power at 17 cubic ft., the high-pressure cylinder would require to be 8 ft. 3 in. in diameter and the low-pressure one 14 ft. 3 in. Any attempt to obtain cylinders of manageable size by giving a higher velocity of piston would involve serious loss of efficiency with any known form of screw, and, as pointed out by Mr. Wright in his evidence before the Committee on Designs, four cylinders would in fact be required in order to give a practicable arrangement.

In a ship of this description, with the machinery so much exposed to projectiles, we should be inclined to divide the cylinder capacity between two pairs of simple expansive engines, with parts interchangeable, even at the risk of loss in point of economy of fuel; and an arrangement might then be adopted which would greatly diminish the risk of disablement of the engines in action, and would add to the safety of the ship, by giving two compartments of reasonable size instead of a single one of objectionable length. One pair of engines could be placed abaft the boiler-rooms as usual, and

the other pair between the forward and after boiler-rooms. Accidents to the forward engines, or the flooding of that compartment, would not affect the after engines, but serious injury to the after pair alone would involve the risk of total disablement. The probabilities are, however, in favor of the connection between the propeller and the forward engines remaining intact, as a shaft of the large size required in this case, placed in the position it would occupy, would stand a good chance of escaping fatal injury. A similar arrangement might be carried out with twin screws.

The protection obtained by providing partial armor, as in the Russian cruisers referred to in an article in our last number, gives many advantages so far as the machinery is concerned; and we think it is quite possible, by a judicious arrangement of the whole of the machinery, to make a ship of this class (provided with the torpedo) a formidable antagonist for a completely-protected iron-clad.

## LARGE ROOF COVERINGS.

From "The Engineer."

We once knew a respectable and trusted septuagenarian civil engineer, always deemed "a safe man," and who had risen from the ranks under Telford, and who had in the course of years collected a large bound-up folio of designs of all sorts taken from executed works, chiefly of Telford and of John Rennie. Whenever he was called upon for a design, out came this folio Bible —the appropriate engineering text was looked out, and Mr. Blank soon came forth for, as it might be, a set of dock cranes, with designs line for line as the *magister* had designed them nearly fifty years before.

It was conveniently safe practice, for had not all these designs been seen to answer their purpose? and it saved a vast deal of trouble and all calculation, which might have proved difficult. But it was often expensive to Mr. Blank's clients, and sometimes struck the younger and outside world as being "behind time"—as when John Rennie's cast-iron crane jibs, or those of Telford, with tensile and strut members of such jibs all framed in oak, made their appearance after the post wrought-iron epoch of engineering had set in. This sort of engineering, according to sample merely, has, happily, nearly or quite died out, but it holds its sway very much amongst the professors of the elder sister art of architecture.

"Precedent," often ill understood as to what it really means, there rules supreme amongst the more mediocre men at least of that noble profession. "Behold the old paths, walk ye in them," is very generally as much the creed of the church architect as of those who are supposed to teach under the roof he has reared.

"Art"—properly so called—fine art—is, except indirectly or occasionally, outside our proper province; we shall not, therefore, enlarge upon the true scope and uses of "precedent," for which we may refer our readers to the lucid views of Viollet le Duc, who, in the noble article "Constructions," in his great "Dictionnaire de l'Architecture," has well pointed out the difference between that slavish imitation of ancient methods and forms, because they *are* ancient, which is in all nations and times a mark of the decay of art, and intelligent reasoning out which evolves its design with a full knowledge and feeling for the old, but with a clear and logical perception of the materials, the methods, the uses and intentions of the new. It was this intelligent reasoning out of their designs in view at once of the past, of the aim and uses of the edifice, of the materials, the skill of the workman, and all other concrete conditions as well, and not a mere construction by "recipe," that, as Viollet le Duc has shown, really characterized the architects, whether lay or cleric, of the middle ages, whose greatest works in chateaux, town halls, abbeys, or cathedrals, still satisfy the cultured man with the sense of united fitness, beauty, grandeur, and durability.

We have been led to these remarks, as the question has risen in our minds, What is likely to be the method of restoration to be adopted as to the partially burnt-off roof of Canterbury Cathedral? Being but partially burnt, it is but too probable that the economic consideration of utilizing what remains may come to the help of blind precedent in deciding that, as heavy timbering and lead cover were deemed the proper

thing when the cathedral was originally roofed, so it ought to be and shall be the right thing still; and so the new roof shall be as combustible and as constantly after a while needing expensive and dangerous repairs as that which has in part perished.

Now, we might quote the very words of Viollet le Duc—the greatest, most practical, and most cultivated of mediæval architects—in our support when we affirm that if the architects of the eleventh to the fifteenth centuries had had iron at their command in the facile forms and abundance that we have, they never would have designed a timber-framed roof; and we do hope that those with whom the decision at Canterbury may rest may determine upon sweeping away what remains of the partly burnt timber roofing, and replace the whole with a well-designed roof-frame in wrought-iron.

This is what actually was done with the fine Cathedral of Chartres, in France, after the ancient roof was burnt in 1835, if we remember rightly. But then comes the question of covering for such a roof placed upon a Gothic cathedral, and upon this point, which has far wider relations, and ought not to be without its instructive lessons to the engineer as well as the architect, we purpose offering some remarks. The iron framing for such roofs should be designed upon a widely different type from that admissible or best for the exposed and visible skeleton of roofing, often of vast span, for railway stations, markets, exhibition buildings, etc.; in all these the covering material is light, and a large amount of elasticity, or even flexure and spread in the structure are allowable. The iron frame over the light and adventurous stone groining of a cathedral must neither grip the walls nor tend to spread them. It must so rest upon the walls as to accommodate itself to gutter, parapet, and pinnacle, and its arrangement of internal parts must be such as to allow the freest possible space and passage from end to end over the groining, nowhere to be touched by iron; and, for reasons chiefly connected with the covering, the frame must be very rigid, and yet its rigidity not obtained by ponderous scantlings and lavish expenditure of material, but rather by the just and mechanical disposition and combination of its parts.

The designs for the iron roofing of the Houses of Parliament, by the late Sir Charles Barry, architect, combined several of these conditions; and though the frame is overloaded with material—even considering the very heavy metallic covering—these roofs would have presented a very favorable adaptation of new material to Tudor architecture had they not been marred by the unfortunate application of plates of galvanized cast iron for the covering. That adoption was the result of imperfect knowledge of the minuter chemical and physical properties of the material which is often as disastrous as absolute ignorance. Sir Charles Barry was satisfied with the common loose dictum—which even still we hear every now and then repeated by engineers and architects, though based upon nothing but imperfect observation—that cast-iron rusts much more slowly than does wrought iron, and he had great confidence in the fact at that time much-vaunted and well "certificated," of invulnerability of galvanized iron when exposed to the corrosive agency of air and moisture. Of three capital facts he seems to have no knowledge:—(1.) That the air, rain, dew, and fog of our coal-burning cities act very differently, and with much greater intensity upon iron—whether cast or wrought—than do the air and precipitations of extra civic places. (2.) That galvanization (zincking) can produce but the most imperfectly continuous coating upon *cast* iron; that all iron corrodes unequally, or by "pitting," cast iron especially, and that the latter is so heterogeneous a compound as to initiate its own corrosion,—so that a thick plate may rapidly eat into holes at places, while its general surface is little affected. (3.) That galvanizing, even when perfectly done—as it only can be upon wrought iron—presents but the most ephemeral resistance to corrosion when immersed in water, or when freely exposed to air and moisture of coal-burning cities.

The result on the Houses of Parliament has been that the thick covering plates of galvanized cast iron were rusty and eating into holes within four or five years after their being laid; and a foreign chemist—armed, it was rumored, by some occult patronage of the late Prince Albert—was brought in to doctor them with "Zopissa's" and "granitic paints," which, we believe, have proved in this case neither better nor worse than the imperfect cover given by inferior oil paints, which have resulted in providing the satisfactory privilege to the scientific inventor, of having a monopoly in making the outside of the platter and cup clean to the public eye by about an annual

coat of paint upon the vast surface of those roofs, the local corrosion of which is going on beneath nevertheless.

Let us, therefore, put any covering of cast or wrought iron plates—galvanized or not—out of the record for roofing of future city or town public buildings. We make no exception, either of the "Lavenant" or other enamelled iron; for, although that thin, glassy covering is unquestionably resistant of corrosion, even in coal-smoke-loaded air, surfaces so treated will not bear walking over, or being exposed to scratches or rubbing of any sort, without loss of their protection. Then, as to lead, we must equally repudiate it, though for a different reason. It must be laid upon a continuous surface of support. We cannot lay it upon any *open* system of rafter and purlin of iron; we must "sheet" over these; and no material suitable for such sheeting is to be found except the old timber boarding; and this alone remaining combustible upon an iron-framed roof, the latter would be much less likely to be destroyed by fire than if the frame were timber also; still the whole structure would not be, as it ought, as perfectly incombustible as the stone groining beneath.

The lead on Chartres Cathedral was laid in breadths of only about 2 ft. wide between the "rollcaps," each sheet being about 5 ft. long, and in thickness about 6 millimetres, or nearly ¼ in. Thus, well laid and so thick, there were considerable surfaces that had been laid in the thirteenth century, and still prior to 1835, free from crack or defect. This, however, is an extreme case, and does not influence what we adduced in a previous impression as to the constant necessity for patching lead roofing.

Pure and well-manufactured metallic zinc in rolled sheets, such as are produced so largely in Silesia and in Belgium, stands in a very different category from that of galvanized iron as a covering. In an atmosphere reasonably free from coal-smoke it is extremely durable, and it even resists tolerably the saline atmosphere of the sea-shore. It is not rapidly acted upon by smoke-laden air, but yet it is acted on, and hence can only with hesitation (notwithstanding some important decisions to the contrary on the Continent, which have so far justified themselves) be recommended for cathedral or other important roofing. It possesses, on the other hand, great structural and artistic advantages. It can be laid upon open iron roof framing without any sheeting beneath, and when properly laid it never "cracks" nor needs repair as lead does. It is not deteriorated by the rough contact of ladders or boot-soles. It lends itself—through its great softness and mouldability when heated to about 300 deg. Fahr.—to the production of the boldest as well as the most delicate or complex artistic forms of the architect; and hence is a precious material for the production of enriched dormers or roof-lights, ridge or gable crests, finials, etc., as may be seen in multiplied instances in Berlin and many other cities of Germany and Belgium, the sky-lines of which are, thanks to this material, often very good and striking.

It has been alleged of zinc that in the high temperature and powerful currents of air, of prolonged or serious conflagrations, the metal itself takes fire and separates into flying flakes of incandescent metal. That the great affinity of zinc for oxygen at or above a red heat may produce this result is certain; but we believe the instances as connected with roofing have been very rare and exceptional, and the evil results exaggerated, if not imaginary. Zinc will not burn at all unless the source of heat to which it is exposed be kept up. If a combustible roof be burnt, fire-brands must fly about, and it matters not whether they be of wood and charcoal or of zinc. But, laid on iron, it is certain that there is nothing either to set the zinc on fire, or, if on fire, to keep up that which soon goes out of its own accord. Although we prefer for all important roofs still more imperishable materials, we think, for the above reasons, that pure sheet zinc, in ample thickness, is well worthy the consideration of and much wider employment by the British architect and engineer.

It is highly probable that the existing dangerous lead-covered and timber-framed outer dome of St. Paul's might be removed, and a new iron frame to the dome covered over with zinc substituted, for not very much more than the value of the old materials, especially the enormous mass of lead, thickly plastered over with the solderings of six generations. The zinc would keep its beautiful grey tone of color permanently, and not present the sooty blackness of the existing lead.

We must pass on from zinc, however, to split-slates, now our almost universal roof-covering. So far as durability and staunchness, coupled with a considerable power of

resistance to disintegration by fire, go, perhaps no material can excel common slate naturally of good quality. In some of the roofing slate districts of the Continent, as in the Ardennes, about Angers, etc., examples exist of its use dating from the twelfth century, and it is known to have been employed in the preceding century, if not before. Probably no more permanent and safe roof can be devised than one of good Welsh "Ton" slates laid on iron framing, tied on with plaited copper wire, and close rendered with good mortar or cement at the under side.

The incurable defect of split-slate roofing, as applied to buildings of an artistic and important character, however, is the baldness and unimpressive character of its surface. The ingenuity and skill of generations of architects and of slaters have been expended in vain in trying to remedy this. In the slate regions of France and Germany split slating can be seen cut into all sorts of fantastic forms—scale-shaped, scolloped, laid in diagonal courses, laid diamond ways, and in a hundred other shapes and ways.

In our own country and time our architects have tried the combination of different colored slates, such as of the rich blue Welsh slate with the green of Delabole, etc.; but the failure of all these methods to remove the bald monotony of a surface made up of plates so thin and with such splintered and thinned off edges as to refuse to give any relief by shadow, proves that the evil is radical, and no more incongruous or degrading character of roof covering could perhaps be placed upon a grand and ornate Gothic church or cathedral than one of what we call "slating."

The most permanent as well as cheapest and simplest roofs in the world have been those of the Greek and Roman architects, composed wholly, like that of the Pantheon, of brick and stone—simply a huge mass of rubble masonry, carried by arch or dome, and externally covered by slabs of stone or flagging.

The early church builders employed this, but soon found out that unless the covering flagging was impermeable to capillary moisture, as well as the joints water-tight, the whole mass of masonry got gradually saturated with moisture, and ceilings below were injured. The method did well enough perhaps for a climate blessed with a long dry season and a fine sun all the year, but the French and German church builders soon found that the case was very different in their climates, and hence they adopted the excellent expedient of separating the covering of flagstones from their arches or groining beneath, by supporting the former on stone purlins laid across and bedded into slender spandrel arches sprung above the groining, so that a free passage for air, and also for examination and repairs, was left between. They also chiselled the flags, hollowing their upper surfaces so as to run the water falling on them rapidly off towards the centre of each width, and giving raised edges, which were covered by stone roll caps, or by other expedients like the old Greek or Roman tiling.

Thus arose those admirable roofs known in France as "*en dallage*," of which one most instructive example to both engineer and architect may be seen in those of the clere-story roofs of Notre Dame at Paris. The "*dalls*" being hand-wrought, must have been expensive; but they were, if of good stone, *i.e.*, if not absorbent of water, imperishable. They were wrought exteriorly into various designs, more or less, however, subservient primarily to their use as water-tight coverings, and those combining the finest play of light and shade and repetition of beauty in form, produced, as may be still seen in several cases, the very noblest architectural effects.

That we might still roof our cathedrals without the use of an ounce of metal of any sort, no practical constructor probably will deny. Very light spandrel ogival arches in brick and Portland cement, with the extrados filled up to the line of the roof pitch or surface, and crossed at short intervals by purlin bars of sawn Welsh slate, could be covered in at once with sawn slate, "*dalls*," rolls, and ridge caps.

But with our existing mechanical and other resources we can do still better. We may cover a stiff iron-framed roof with suitably formed "*dalls*," machine-wrought in Welsh or Irish sawn slate, that shall possess all the beauty and character of the ancient examples.

Slate slabs of 5 ft. or 6 ft. long, by, perhaps, half that in width, of say, 1½ in. in thickness, could be at a cheap rate hollowed down by revolving cutters, so as to leave the needful raised edges round the sides and ends at whichever surface of the slab required, and raised or incised ornaments might thus be produced at the same time in

endless variety on the exposed surfaces. When finished the average weight of the slab would be only about that of an equal surface of, say, $\frac{3}{4}$ in. to 1 in. in thickness, and such slabs would remain steady in place in the highest winds by their own weight.

We suggest this not only to our architects, but to those interested in our great slate industry, to whom it would rapidly give a new and lucrative branch of trade; for such machine-made slate "dalls," or tiles, as perhaps we might call them, would soon be valued by the architect and builder for the roofs of many other classes of buildings as well as ecclesiastical ones. The color or tint of slate, whether blue or green, is not liable to much objection, and here we should obtain what slating wants—fine play of surface lights and well cut shadows. The reference to color, however, suggests to us that in the existing state of our ceramic arts, flat glazed tiles, quite as large as "dall" slabs, could be readily produced by our potters were the demand for some of them once assured. The giving a light—white, grey, or buff—surface color to large tile slates, such as we refer to, by means of a surface opaque enamel burnt on, has never, we believe, yet been done, and that is still needed to enable a tile-slate roof of great dimensions to be produced with the full beauty of which it is susceptible.

In Southern Italy, the former kingdom of Naples, and in Sicily, roof coverings of great beauty are seen upon ancient churches and monasteries, formed wholly of parti-colored glazed tiles—white, black, yellow, blue, brown, etc., laid in various patterns. There under a brilliant sun, and on a scale not too large, the effect is often very charming. But too much or too bright colors do not suit our dull climate or buildings, nor very large roofs. On buildings of great magnitude, ecclesiastical or not, or in whatever style, in which the roof properly forms an important feature in the general effect, the material of the roof covering will best be of light but neutral—at least not too boldly pronounced—color, that shall harmonize with the prevailing tint of the building itself, carrying the eye upwards to the sky-line above.

We believe that all the aims, then, structural and æsthetic, of the higher class of roofing, may be fulfilled by wrought iron framing, covered in with machine-carved slabs of sawn slate, or with those formed and decorated by the improved apparatus and the decorative resources of the potter.

## ROADS OR RAILWAYS.

From "The Engineer."

At the present time, when both iron and coal have reached unprecedented prices, the construction and maintenance of railways which are essentially dependent upon these two materials for their existence and utility, become a subject of serious consideration. It is not, however, at home, where both coal and iron can be obtained, but abroad, where they cannot, that the question becomes invested with the greatest amount of interest. But even at home the significant fact cannot be overlooked, that a contract has been recently entered into with a French company to deliver at an English port 250,000 tons of coal. The instances to which we especially allude in connection with our subject are those which concern the future prospects of countries in which either coal and iron do not naturally exist, or have hitherto remained undisturbed in the earth. Evidently there is one of two courses open to the inhabitants of such countries if they are desirous of advancing in the path of civilization. One is to develop their own natural mineral resources, and the other to avail themselves of those of other nations. The former, in a perfectly new and unopened-up country, is a work of considerable time, and, moreover, cannot be carried out without the existence of some routes of intercommunication. The latter is a question of expense, and depends also upon the condition the country is in with respect to roads. It is not too much to assert that the cost of the freight of coal and iron in a country in which scarcely any except "bridle" roads exist, practically prohibits the introduction of these valuable materials. The construction of railways in a country so situated evidently becomes undesirable from several points of view. In the first place, their cost would be enormous; secondly, they are not needed; and, thirdly, they would not pay. Railways cannot feed themselves, as our

Indian experience has taught us. To come near home, let us take a country similar to Greece, in which bridle-roads are numerous, and high roads very few and far between. It is true that the cost of freight to Patras or any other port is not of a prohibitory character, but the transport of materials in the interior of the country would, independently of the cost, be in many cases absolutely impracticable. The same statement holds good with double force for many States in South America, and, in fact, for numerous countries over the whole face of the globe, which are possessed of immense mineral wealth, but totally unprovided with the means of procuring it, and transporting it, and rendering it generally productive and beneficial to the inhabitants themselves and the rest of the world. It is idle to talk of establishing railways in countries so entirely destitute of all routes of communication. Roads are the necessity; good common roads well drained, well metalled, or with a hard top surface of some sort, laid upon a sound solid substratum. Whether in the laying out of these primary roads it would be advisable to take into consideration the possible subsequent conversion of them into railroads, is a matter which must depend upon the local features of the country, and the circumstances attendant upon each particular case. As a rule we should be inclined to advise that the two ideas be not jumbled up together. Let the road be laid out and constructed for the exact purpose for which it is intended. Alterations and conversions are at the best but makeshifts, and seldom afford that complete satisfaction which results from works which are intact in unity of design and execution.

Imitation is not always judicious. It is frequently very unwise to adopt in one instance a conclusion that has been arrived at in another, unless the premises in both cases are precisely identical. It would be well if this were borne in mind by those who advocate in a reckless manner the introduction of railways in wild and undeveloped countries in which there is not a single road, in the most literal signification of the term. The advantages that we ourselves enjoy from a regular system of internal railway communication cannot be transferred instantaneously to another country which is totally destitute of that other and almost equally important means of transport, ordinary roads. Those who maintain that they can, must either be wilfully or ignorantly blind to the fact that before a foot of railway was laid down in England, there existed a complete network of high roads throughout the whole land. Our turnpike roads can compare with any in the world, both with respect to dimensions, condition, and general contours. Before the railways in England were constructed, the feeders in the shape of roads were ready to supply them. In a word, the roads were made first and the railways afterwards, and although this was a purely fortuitous sequence, yet experience has since demonstrated that it is the proper course to pursue, the correct order of events, in all new countries. To every rule belong exceptions, and there are some exceptions to the one we have laid down. It is quite possible that the construction of a railway in a new country may be of greater importance than that of an ordinary road. The line from New York to San Francisco is an excellent example in point. But upon a little reflection it will be seen that this great continental line is not so much a route of internal as of external intercommunication. It is, in fact, a national highway. It unites the shores of the Atlantic with the coast of the Pacific, and is now the principal connecting link between Western civilization and Oriental barbarism. Lines of railway similar to this are *sui generis*, and owe their origin not so much to the necessities of the district through which they pass as to the demands made for their construction by the wants and wishes of the world at large. There is no doubt that the Central Pacific line will ultimately prove of immense benefit in opening up the internal resources of the States; but until feeders and branch lines are established its utility will be chiefly confined to the purpose which really dictated its formation.

It will be admitted that in far distant lands where the transport of materials into the interior becomes impracticable when any separate portion exceeds in weight the tenth part of a ton, it is of the greatest possible advantage that those which are necessary for the construction of any engineering or architectural work should be found in the country itself. It is true that there are many varieties of roads, and in this respect there is a similarity between them and railways. There are unquestionably numerous gradations included between the corduroy lines in parts of the far West, and the permanent way of the London and

North-Western Railway. The same diversity will be apparent between the open path or track, only distinguishable by trees that have been "blazed," or by the wheel ruts of passing vehicles, and the modern boulevard extending from Westminster to Blackfriars. The three essentials—timber, earth, and stone—necessary for the construction of common roads can be found in every country, and frequently along the line of route itself, or in close proximity to it. The value of this consideration cannot be overestimated, especially in the case of the inland territories of some of the large continents. In some of these the cost of the freight alone for a single ton of goods from an English port would reach £40. It is evidently, therefore, of the utmost importance to be able to open up a country placed in this unfortunate position, with such means as are to be procured from the land itself, the quarries, and the forest. In a new, undeveloped, and perhaps but partially explored country, the first cost of work is everything, and the skill and practical management of the engineer are best displayed in availing himself of the two cheapest resources at his command. These are raw materials and unskilled labor. The farther, to use a familiar phrase, he can make these "go," the greater reduction he will effect in the first cost of the work. This item will evidently vary with the width of the road, although the character of its formation will have also some influence upon it. In India —where roads are the urgent want, in spite of the railways which have been made there—the roads are divided into four classes—first, second, third, and fourth. Of these four, two, viz, the first and the fourth, may be omitted from our category, inasmuch as the former is of too expensive a character, and in excess of the requirements of a country such as South America or Australia. Especial cases may arise where circumstances might warrant the adoption of a first-class road, as, for example, when it was to serve as a main artery to which a large number of secondary or branch roads converged. As the principal commercial outlet of a country, its construction would be a matter of consideration in which the chief points to be attended to would be the amount of the traffic to be accommodated and the national finances. The roads included under the fourth class are neither drained nor metalled, and are little better than a mere track roughly levelled and cleared, and being unprovided with bridges or culverts are consequently impassable at certain points during times of flood and in the winter season. They are in fact nothing more than third-class roads in their preliminary stage. The difference between a second and third-class road consists in their respective widths, the depths of metalling and substratum, and the dimensions of the bridges and drains. It is evident that the latter must depend almost entirely upon the physical character of the district through which the road passes. To whatever class the road may belong, with the exception of the fourth, the waterway which must be given to the culverts and bridges is altogether independent of the position it occupies in the scale of construction. It follows from this that a road might rank in the third class so far as its width and other dimensions were concerned, and yet belong to the second or first class with respect to the waterway of its drains, culverts, and underbridges.

While we admit the necessity of paying great attention to so important an item in all engineering works as the cost, we are not disposed to concur in the views of those who regard it as the only true test of merit. The proper axiom is efficiency first and cost afterwards, and neither must be unduly sacrificed to the other. In these days of cheese-paring and false economy, the cart is in this respect unfortunately often put before the horse, and the subsequent unharnessing of the animal, and placing him in his correct position, frequently entails a greater expense than would have been requisite for the proper performance of the operation in the first instance. Notwithstanding that there are numerous thorough estimates of the cost of roads in even and uneven grounds, it is impossible to adduce a rule which shall be generally applicable, or which can be regarded in any other light than that of an approximation. Each example has its own especial circumstances and conditions, which cannot be ascertained without an actual survey of the district which is to be opened up for traffic. In some cases the land is obtained gratis, in others the materials can be procured on the same easy terms, and in others, again, both the land and materials are in the hands of the Government, and are delivered over free to the concessionaire, so that the expenses are limited to those of plant and labor. It is obvious that as one or more of these con-

ditions may obtain in any particular instance, no general rule can be laid down with regard to cost, omitting all consideration of the great influence which the physical features of the country exercise upon this item.

There is one point in connection with our subject to which particular attention should be directed. It is the necessity for a careful and searching preliminary reconnaissance of the route to be selected for a road, combined with an accurate survey, and a close series of levels, both trial and complete. Railway engineers are very apt to consider that there is no need for the same accuracy with respect to the surveying, levelling, laying out and designing of a road, as there is for similar operations when railways are concerned. This is a great error, and one that can be perceived to be so on reference to existing roads which have been so laid out as to involve a rise or fall of several hundred feet more than the total difference of level between their respective termini. Of this fact we may be certain: the more care and the more time that are reasonably spent in determining the directions and gradients of a road in a rough country, the cheaper the road will prove in construction and the better adapted it will be for its duty.

## RAILWAY BRAKES.

From "The Engineer."

It has been said that until a bishop is killed on some of our railways no effectual measures will be taken to prevent railway accidents. Whether the death of a dignitary of the Church would be followed by a direct and immediate improvement in the working of our railway system will, we hope, long remain undecided. Yet it is possible that a bishop might be put to a worse use. The questionable point is as to whether his death by railway violence would, indeed, insure a total exemption from railway accidents of the more important kind. While any uncertainty attends the question it would not be fair to expect a bishop to make a martyr of himself for the good of the community. It is not unlikely, however, that a remedy less terrible may be found. It is probable that if railway companies could only be induced to look at the matter from a common-sense commercial stand-point, all the benefits would be obtained which it is proper to hope would be secured by the annihilation of a dignitary of any kind. We are about to try to make it clear to railway companies that it would be directly to their interests to adopt means, ready to their hand, by which they might get rid of the worst class of accidents in working their lines.

About 70 per cent. of all the so-called accidents which occur on British railways must be classed under the head of collisions. It is impossible to have a collision without losing money. The experience of years has fully demonstrated the truth of this proposition. A little collision may be had for an outlay of about £25. A great one involving considerable loss of life can scarcely be had at a less price than £20,000. We have no means of determining accurately what is the average cost of a collision, but we believe that we shall not be far wrong if we estimate the direct loss to such a company as the London and North-Western at about £10 per mile per annum. This is meant to include all expenses, as well as those incurred in effecting trifling repairs to engines and goods trucks, due to a small "pitch in," now and then, as the weightier matters of compensation, legal expenses, and doctors' bills, proper to a heavy collision. An expenditure of from £10,000 to £30,000 a year on railway accidents, is nothing abnormal, as the shareholders of not a few of our great lines know to their cost. Speaking after the dictates of plain common sense, is it not a puzzle that railway companies will not exert themselves to save this money? We do not write like outsiders addressing the daily press in the "silly season;" on the contrary, we speak with a more or less intimate technical knowledge of what is and what is not practicable in railway working and railway management; and in the full light of this knowledge we assert that collisions might be rendered exceedingly rare if railway companies and their engineers would only take the trouble to avoid them. To make our meaning clear we must explain ourselves a little. There will always be accidents on railways due to the negligence of passengers and railway servants. Men will insist on entering carriages in motion;

porters and guards will walk incautiously on crowded lines; axles will break; rails will give way, and trains will run down embankments and fall through bridges. All these accidents are in a sense beyond human control, but they represent very minute loses to the railway companies as compared with those entailed by collisions, which, as railway men know, recur with a frequency undreamt of by the general public. It must be admitted, then, that by eliminating collisions from the list of casualties to which railway plant is subject, a very large pecuniary saving would be effected on nearly every line in the kingdom. This much premised, let us inquire to what cause collisions may be properly attributed. Of course we shall be told that they are due to the negligence of signal-men or drivers, to fogs, to points acting badly or not at all, and so on. Now, we dismiss all these statements at one swoop. They carry no conviction—they do not touch the truth. All collisions, with the single exception supplied by wagons breaking away on an incline, result directly from the fact that a railway train running at speed cannot be stopped promptly. This is the gist of the whole matter. Signals, and telegraphs, and complicated instructions, are all rendered necessary because a driver cannot pull up an express train travelling at forty miles an hour in a hundred yards. There is no disputing the accuracy of this proposition. No one ever yet heard of an instance in which many yards did not intervene between the trains when it was discovered that a collision was imminent. If only this space could be utilized in bringing the advancing train to rest, all danger would be at an end. If our readers accept this proposition as true—and they cannot elude it any more than they can combat in—then is half our work accomplished. We have made it plain that by conferring the power of stopping at will within a distance of about a hundred yards, collisions of the more serious kind, if not of every kind, would become matters of history only. They would have no regular existence—the vitality of the evil would be removed forever.

Now, how has it come to pass that railway men generally completely ignore this great fact, and content themselves with providing such means of stopping trains as are afforded by the tender-brakes and those on a couple of guards'-vans—brakes so constructed that they cannot, such as they are, be got into operation until time, every second of which is worth from £10 to £100, has been wasted? It is very difficult to find an answer. No locomotive superintendent, so far as we are aware, has ever invented, or at least applied, a good continuous brake of his invention on the line under his charge. All the best brakes have been invented by outsiders, and, literally, forced on the companies. In this matter of brakes conservatism has fairly run mad. In every other department of railway construction and working, daily improvements have been effected for the last thirty years; but the popular brake of to-day is identical in every respect with that used in the infancy of the Manchester and Birmingham line. Why this should be the case baffles us. The steady adherence of railway companies to an old and imperfect device can only be regarded as one of those psychological problems which meet every thoughtful student of the social relations of life. It has been urged that the railway companies can get nothing better than the old brake. Even if this were true—and it is false—still the question would remain, why have they not tried? and they have not. Again it is asserted that a really effectual brake would cost too much money. This can hardly be the reason, because we find companies spending money freely on costly signalling apparatus, rendered necessary solely because the trains have bad brakes, and the cost of one serious collision would pay for fitting up with efficient apparatus nearly every passenger train on a first-class line. The cause must be sought somewhere else, and we confess that we cannot find it, unless an apathy, which is almost criminal, results from the belief that what answered many years ago will do well enough now, and that a large expenditure for new brakes would be regarded as an illegitimate and unprecedented waste of funds, while disbursements on the score of collisions are regarded as strictly normal and legitimate expenditures proper to all railways, and as unvoidable as the income-tax collector.

It is perfectly well-known that it forms no part of the policy of this journal to advocate the adoption of patented inventions. It is our policy, however, to advocate the adoption of substantial improvements in the arts of construction, whether they are or are not patented. It is without hesitation, therefore, that we state our conviction that by

the adoption of such a brake as that recently introduced into this country by Mr. Westinghouse, collisions might cease to have any important existence. It is right that we should explain why we single out the Westinghouse from many other systems of continuous brake, more or less efficient, which have been tested in this country. The reason is this :—No locomotive superintendent or manager is justified in incurring a large expenditure on an unheard of or comparatively untried invention. We know nothing of the existence of any other form of continuous brake which has been so extensively used as that we have named. In their immediate effect all continuous brakes are pretty much the same, when once the wheels are skidded. The difference lies in the means by which the wheels are skidded. We believe, in common with a very large body of engineers, that Mr. Westinghouse has solved the problem of constructing a good continuous brake. It is quite possible that a far better brake may be invented, but with this we have nothing to do. The Westinghouse brake has passed far beyond the limits of the first stage. Its construction occupies hundreds of hands, and all the resources of a manufacturing establishment of great dimensions in the United States. All the principal American lines use it already, or are adopting it. Many hundreds of the little air-pumping engines have been made. The operation of the brake is eminently satisfactory. Why should it not be adopted extensively in this country ? We are not hard to please; we do not, be it understood, write to advocate the adoption of the Westinghouse brake, but we write to advocate, nay, to insist on the general adoption of a first-class continuous brake on our railways, no matter who is the inventor, and we cite the Westinghouse brake because it affords a direct and complete answer to those who argue that there is no good continuous brake in existence, and that they will wait till one is invented and tested. We cut the ground from beneath these gentlemen at once, by asserting that all that can be required is provided ready to their hand. It remains to be seen whether among the multitude of our readers one can be found to argue that we have advanced a single statement which is contrary to truth, reason, and common sense.

## EAST AFRICAN RAILWAY EXPLORATION.

From "The Engineer."

Physical geography, a science eminently practical, is devoid of one characteristic charm that belongs to well-nigh every other science—it is not illimitable or interminable. Give a mathematician a piece of chalk, set him before a blackboard, and he might go on devising new combinations even to infinity, if life could be so extended. It is the same with most other sciences than the one to which reference is made. Physical geography is so far from interminable or inexhaustible, that the surface of a sphere some eight thousand miles across comprehends it all. North and south in the high latitudes conterminous with either pole, there exist, indeed, two climatic belts, which by their extreme cold may ever interpose a barrier to geographical exploration, though even this limit is not taken by all physical geographers as a matter of course. Mere heat of climate is no effective barrier to travel, and even unhealthiness is an impediment which experience has proved to be in most cases remediable. Already physical geography gives signs of approaching its limits. Travellers' tales are not so startling as they used to be. Nothing about unicorns, dragons, flying serpents—creatures that one may see depicted in many an ancient book of travel—not to mention the basilisk, which must of course have been found dead, as the animal would infallibly kill the rash individual who should look upon it living. A dead basilisk might have been found in the desert, but in what manner the Dutch traveller Foersch managed to obtain a sketch of the upas tree, as it figures in his volume, is less apparent. According to the reputable Dutchman, this very tree killed everything and everybody that approached it within twenty miles —and still he sketched it. Dragons, unicorns, and flying serpents have long been confided to heralds' keeping, and even the gorilla, which, as described by Mons. du Chaillu, somewhat revived the emotions of our youth on reading travellers' tales, is now shorn of the terrors which environed

him, lowered to the insignificant grade of a big monkey, harming nobody, and so great a fool that, having built himself a house, he sits on the roof in a thunder-storm instead of getting under it.

From an engineering point of view we can only be expected to take a remote interest in many of the questions which have been mooted, and which are now with more zeal than courtesy debated in reference to the great watercourses of South-Eastern Africa. Whether the Nile really begins by two head waters from the two equatorial lakes, Victoria Nyanza and Albert Nyanza respectively, as was thought to have been definitely proved by Grant, Speke, and Baker, or whether, as Livingstone now believes, its origin is referable to head springs still farther south, is to all except systematic geographers a matter of secondary importance. Contemplating the Nilotic riverain with reference to facilities of locomotion, the fact has been long since patent, that, owing to various impediments, there is no hope of establishing an effective Nilotic communication from the two great lakes of Baker, Grant, and Speke, northward to the Mediterranean. Whether Livingstone's great river, the Lualaba, actually joins the Nile; whether it flows into some vast inland lake; or, lastly, whether it prove the head water system of the Congo, is a speculation of deep scientific interest, no doubt, but at the same time one of no practical importance. Regarded from an engineering point of view, one would rather it should turn out to join the Congo than the Nile, seeing that under the first eventuality a navigable water communication might be demonstrated to be practicable to the West Coast of Africa from the point of about 10 deg. south latitude, and uncertain longitude; but probably 10 deg. west of the western limit of Lake Tanganyika.

While disclaiming, as beyond our proper functions, any argument on the hydrographical points which elicited such warmth of feeling—and, we are sorry to add, such discourtesy at Brighton—we may still be allowed to express an opinion. It seems, then, to us improbable that the river system described by Livingstone really does communicate with the Nile. Mr. Stanley stated at Brighton that the Albert Nyanza has nothing to do with the Lualaba. That is proved, he stated, by the fact that between them exists the great lake Tanganyika; and except previous levellings are very much at fault, there can be no communication between Livingstone's riverain and the Albert Nyanza. In point of fact, Livingstone himself expects no such solution of the problem. By a process of elimination he seems to infer that, if the waters of his new riverain do not reach the Nile through the Bahr el Gazal, they can form no part of the Nilotic system. Against this hypothesis there would seem to be insuperable evidence, though of purport unknown to Livingstone. Now, both Petherick and Captain Grant furnish testimony in respect to the Bahr el Gazal wholly irreconcilable with Livingstone's hypothesis. They represent it to be a reed-embarrassed, sluggish river, of far inferior dimensions to the Lualaba which, according to Livingstone, should be its effluent.

However, all this is beside our mark. What we have in view is the commercial opening up of a rich and well-peopled region which geographers not so very long ago complacently assumed to be an unproductive desert. Dibdin in his autobiography states that, although an indifferent painter, he was once called upon to depict a theatrical battle scene, and had to do it. He trembled at the task at first, but ended by finding it easier than he expected. Whenever uncertain as to form he painted smoke, and in this way he succeeded to the manager's content, if not to his own. Mapmakers, when laying down the African continent on their charts, were not so long ago in the habit of filling in blank spaces by desert sands. The dreary prospect has vanished now. The equatorial lake system of South-Eastern Africa has been so far explored that a tolerably correct notion may be formed of its natural endowments.

Nobody will accuse Dr. Livingstone of drawing on his imagination, or place him in the category of sensational travellers. So far from exaggerating the peculiarities of men or things he meets with in his travels, the good Doctor perhaps fails in the other extreme, wishing friends at home to believe that native Africans, instead of belonging to a race inferior, mentally and physically, to his own, are on terms of equality as to the first, and of superiority as to the second. It may be, as he affirms, that certain types of negro ladies—albeit, coffee-colored as to skin—could hold their own in presence of European belles, or it may be that Livingtone's judgment on that point is warped through a too exclusive

contemplation of one particular style of female beauty. Whether, again, in a comparative show of negro aristocracy and of members of the Anthropological Society, our *savants* would come off second best, as Livingstone gives his readers to understand, is a question we hope more open to debate than the Doctor would wish us to believe. Making allowance for this amiable tendency to think and speak the best of people he is thrown amongst, it still seems quite clear that the African races from amidst whom Livingstone writes, are by no means so debased a lot as, under the circumstances, might have been expected. Individuals of a certain tribe do, indeed, eat men, but they would not seem to be cannibals in the same sense as *were* the Maoris, and as *are* the New Caledonians. As regards these East African cannibals, the Doctor's impression evidently is, that their cannibalism has some religious or superstitious significance. Modified cannibalism notwithstanding, the Manyemas favorably compare with the highest amongst aboriginal races. It has been customary to look upon the North American Indian type as furnishing the best example of an aboriginal race for moral and intellectual endowments, but it would really seem that the Eastern African is higher in the possession of most qualities that go to make up manhood. A favorable characteristic of the East African equatorial races is the tendency to form village communities, to effect clearances in forest wastes, to breed live stock, and cultivate a no inconsiderable amount and variety of garden produce. A people that can boast of swine and goats, tame buffaloes, and domestic fowls, must have already elevated themselves many degrees above primæval barbarism, and further shown by the elevation a capacity for rising still higher. They extract iron and copper from the respective ores, and manufacture tools and utensils. Quite clear, then, is it that one has not to do either with a totally barbarous or a wholly incompetent population.

If the native races of South-Eastern Africa are promising as to their endowments, what shall be said of the localities? A region where ivory is of so small local value that it lies in forests for rodents to sharpen their teeth against; where iron ores abound; whence copper may be drawn in illimitable quantities; where trees grow so dense as to veil the tropical sun rays—so high that a shot gun fails to bring down birds perched on the tops of them; where the climate even now is good, and if forest clearances were effected would be better—such tracts must be worthy of exploration, even in the interest of pounds, shillings, and pence, even did no such problem remain for solution as discovery of the Nilotic sources. Perhaps the best phase of the commercial aspect has been omitted from the preceding summary, viz., the appreciation in which calico and other Manchester goods are held by the natives. Calico, brass and copper ornaments, beads—these articles seem to represent the currency of the East African races. Perusing Livingstone's late despatches with a map of Africa before one, it needs some concentration of thought to bring in evidence the difficulties which Livingstone has had to surmount, and other difficulties which still weigh heavily upon him. He appears to be somewhere about 500 miles from the coast—as the crow flies, not so much. On a map of Africa the distance looks trifling, and, estimated by modern standards of travel in European countries, a trifle it is. Even in Europe, however, a traveller may come to conclude that the difficulty of travel bears no necessary relation to expanse passed over. Half a-dozen miles on mule-back in Spain is, for discomfort and fatigue, equivalent to more than a railroad run from St. Sebastian to Alicante. Is it over much to hope that in these days of plethoric capital and ardent speculation a railroad may be promoted for throwing open Eastern Equatorial Africa? The undertaking of such a scheme would of course depend on the answer given to the question whether it would pay. Capitalists would look coldly on any scheme for driving a railroad into Africa from the east with the object of mere geographical exploration in view; but demonstrate to them the feasibility of adequate returns on capital invested, and means would be forthcoming. In these days it may be quite true that most things are possible to the engineer who commands sufficient pecuniary means. The Suez Canal and the Mont Cenis Tunnel lend color to the statement; but still, were it a necessity that a line of railroad starting from the coast opposite Zanzibar and trending inland, should need a Mont Cenis tunnel, capital might shrink from so great an expenditure on such a field. On the contrary, no physical obstacle of importance would seem to exist. No mountain to be tunnelled, no important river or chasm to be bridged.

Nothing but a terrain moderately level, and for the most part thickly wooded. Sleepers might be obtained on the spot; only rails and rolling stock stock need be imported. Fuel would be on the spot, too —wood in abundance, and conceding that wood would be inferior to coal or coke, yet it is competent to do good service. We may be one-sided as to our view of the scheme, but there is much to recommend it. So long as the old school-book teaching held credence about Central Africa being a waste of burning sand, the problem of opening it up offered no commercial incentive; but since modern geographical discovery has proved this vast continent to possess regions of abundant fertility, a dense population, and a not uncongenial climate, the commercial features of the case have wholly changed.

Regarding the scheme from a point of view wholly commercial, no reference has been made to native amelioration, physical or intellectual; to the diffusion of Christianity, or, above all, abolition of the slave trade, which seems to be characterized by atrocities equal to any perpetrated on the other side of the African continent. Such amelioration, however, would follow as a matter of course; indeed, even though the establishment of a railway failed to show prospects of such satisfactory return on capital as we believe, it might still be worth while for philanthropists having the suppression of slavery in view to look well into the features of this project.

In making this suggestion, we have not taken into account any royal or territorial interest; but on this ground it would not seem that much difficulty need be apprehended. Already there exists a certain tract opposite Zanzibar which owns allegiance to the British flag, and at which operations would have to be commenced. The Sultan of Zanzibar, if alive to his own interests, would do his best to promote a scheme that by extending trade must necessarily help to fill his exchequer; and, lastly, the wealthy Banians—men who appear sufficiently alive to the main chance—might come to understand that their traffic in African flesh and blood being irretrievably doomed, the iron road, if made the most of, would secure to them a fair indemnity.

## EXPERIMENTS WITH THE CAMERON STEAM PUMP.

By M. H. TRESCA.

Translated Abstract from "Annales du Conservatoire."

At different times steam engines have been constructed, in which the distribution of steam has been automatically made by the action of successive pressure upon attachments to the slide valve. Cameron's pump consists of such an engine and of a pump set with the same axis, so that the two have the same piston rod and stroke.

By this arrangement all communication of motion to the pump or the fly-wheel is avoided. The distribution is made in a simple way by means of catches disposed in the top plates of the steam cylinder. These act on valves which are shut by the action of the steam cutting off all communication.

Toward the end of each course the piston pushes back one of these catches, and the steam then acts upon a special piston in the slide box, which alternates the action of the parts of admission and discharge. An outside lever is used in starting, which displaces the small shaft that carries the two pistons, one at each end.

At the request of the constructors, MM. Tangye, we have examined this machine with reference to its economic results. The first disadvantage we find is that it does not utilize the steam at full pressure, so that the results of this examination apply only to provisional or portable machines.

The dimensions of the pump were as follows:

| | | |
|---|---|---|
| Piston stroke (2 feet English) | 0m. | .6093 |
| Diameter of steam cylinder (8 in. 1 line) | 0 | .2065 |
| Total piston-surface | 0mq. | .0335 |
| Surface of piston without rod | 0 | .0329 |
| Mean surface under action of steam | 0 | .3332 |
| Stroke of pump piston | 0m. | .6093 |
| Diameter of pump piston | 0 | .1523 |
| Total surface of pump piston | 0mq. | .0182 |
| Surface without rod | 0 | .0176 |
| Mean surface | 0 | .0179 |
| Volume of stroke | 10? | 909 |

The apparatus was subjected to a number of experiments, with results as shown in the following table. The water discharged was gauged in reservoirs of great capacity. The number of piston strokes was registered by a meter, and a pressure indicator furnished diagrams of work done.

| Number of experiments. | Time. | Number of forward and back strokes. | Volume measured. | Volume of water discharged. | Percentage. | Height raised. | Work in water raised. | Work per second. |
|---|---|---|---|---|---|---|---|---|
| | seconds. | | me. | me. | | m. | km. | km. |
| 1 | 3700 | 686.5 | 13.872 | 14.979 | 0 926 | 7.27 | 100849 | 27.24 |
| 2 | 1720 | 647 | 13.872 | 14.117 | 0.982 | 7.28 | 100988 | 58.71 |
| 3 | 1285 | 630 | 13.872 | 13.646 | 1.009 | 7 28 | 100988 | 78.59 |
| 4 | 1180 | 643 | 13.978 | 14 029 | 0.996 | 13.35 | 186606 | 158.14 |
| 5 | 1780 | 673 | 13.978 | 14.684 | 0 951 | 13.35 | 186606 | 104.83 |
| 6 | 5521 | 639.5 | 13.978 | 13 953 | 1.001 | 13.37 | 186886 | 35.79 |
| 7 | 1471 | 650 | 13.872 | 14 182 | 0.981 | 10.36 | 143714 | 97 70 |
| 8 | 2535 | 669 | 13.872 | 14 597 | 0.950 | 11.18 | 155158 | 61 20 |
| 9 | 1648 | 628 | 13.376 | 13.702 | 0.976 | 4 30 | 57517 | 34 90 |
| 10 | 1055 | 596 | 13.376 | 13 004 | 1.028 | 4.30 | 57517 | 54.51 |
| | | | | | 0.982 | | | |

This table shows a very satisfactory percentage of effect, corresponding to 0.982 of the volume generated by the motion of the piston. The alternating action was very regular, and the slight shocks at dead point did not hinder the action of the valves.

To appreciate the useful effect of the machine we must take into account the work expended on the piston and the quantity of steam used. Our investigations refer only to the first point, and the results are given in the following table:

| | Number of diagram. | Pressure in boiler. | Surface of diagrams. | Mean pressure. | Work per second. | Work in water lifted. | Effective work. |
|---|---|---|---|---|---|---|---|
| | | at. | $m/m^2$ | at. | | | |
| 1 | 1 | 4.70 | 890 | 1.198 | 92.95 | 27.24 | 0.293 |
| | 2 | 5.00 | 910 | | | | |
| | 3 | 5.30 | 1050 | | | | |
| | 4 | 5.10 | 1040 | | | | |
| 2 | 5 | 4.80 | 1270 | 1.497 | 235.30 | 58.71 | 0.249 |
| | 6 | 4.75 | 1230 | | | | |
| | 7 | 5.00 | 1390 | | | | |
| | 8 | 4.85 | 1540 | | | | |
| 3 | 9 | 4.80 | 1480 | 1.707 | 349.71 | 78.59 | 0.224 |
| | 10 | 4.80 | 1510 | | | | |
| | 11 | 4.90 | 2130 | | | | |
| 4 | 12 | 5.00 | 2090 | 2.362 | 537.89 | 158.14 | 0.294 |
| | 13 | 4.80 | 2080 | | | | |
| | 14 | 4.70 | 1770 | | | | |
| 5 | 15 | 5.00 | 1930 | 2.177 | 343.91 | 104.83 | 0.304 |
| | 16 | 4.90 | 1930 | | | | |
| | 17 | 5.10 | 1400 | | | | |
| 6 | 18 | 5.20 | 1460 | 1.841 | 94.17 | 35.79 | 0 380 |
| | 19 | 5.15 | 1540 | | | | |
| | 20 | 5.20 | 1550 | | | | |
| 7 | 21 | 4.80 | 1560 | 1.803 | 330.70 | 97.70 | 0.295 |
| | 22 | 4.65 | 1540 | | | | |
| | 23 | 5.00 | 1410 | | | | |
| 8 | 24 | 5.10 | 1450 | 1.838 | 202.71 | 61.20 | 0.301 |
| | 25 | 5.10 | 1420 | | | | |
| | 26 | 5.10 | 970 | | | | |
| 9 | 27 | 4.85 | 890 | 1.175 | 187.1 | 34.90 | 0.186 |
| | 28 | 5.10 | 960 | | | | |
| | 29 | 5.10 | 960 | | | | |
| | 30 | 4.50 | 1060 | | | | |
| 10 | 31 | 4.50 | 1070 | 1.264 | 298.47 | 54.51 | 0.182 |
| | 32 | 4.80 | 1140 | | | | |

It is seen that when the pressure in the boiler is constant, that transmitted to the piston necessarily diminishes as the resistances become less. The admission is good when the orifice is free; but in case of stoppage there is a constant decrease of pressure during admission, and a constant increase of counter pressure during escape.

For a height of water amounting to 4m. 30 the theoretic pressure would be reduced to 0.50 atmos., if the steam and water-piston have the same sectional area; and with the actual sections it would be reduced to $0.50 \times \frac{18}{30} = 0.27$ atmos. above atmospheric pressure.

We observe that the ratio of effective work to that expended on the piston varies, according to circumstances, from 0.182 to 0.830, giving a mean of 0.27. As the lowest percentage was for the lowest of the reservoirs employed, we may assume a percentage of 0.30 per water raised 7 metres.

We conclude that an ordinary engine of small dimension gives about 0.75 of the work indicated; a pump attached would not realize more than 0.50. The two combined would give a percentage of $0.75 \times 0.50 = 0.375$, or about a quarter more than the Cameron pump.

Still the advantages of ease of setting up, and diminution of expense, might compensate in a case in which water is to be carried to a great height. But it must be remembered that the steam is rapidly spent in the long cylinder with its extensive cooling surface, so that this pump, however ingenious, cannot be employed in ordinary cases. Its use is limited to those cases in which there is an abundance of disposable steam, and when there is immediate need of a large quantity of water. In these cases it would be of service as an auxiliary machine.

## METROLOGICAL REFORM.

From the "London Morning Journal."

The enormous advantages of the metric system as a substitute for those now in common use in England and America daily becomes more extensively understood, even by those who have no direct connection with import or export trade, and who take but a very small amount of interest in scientific literature, whether English or foreign. To assist in the diffusion of a knowledge of the benefits derivable from the unification of the weights and measures of countries trading with each other, another thousand copies of the revised edition of the very excellent address delivered before the recent Convocation of the University of the State of New York, by Dr. Fred. A. P. Barnard, President of Columbia College, New York City, has just been printed and issued (through Mr. Van Nostrand, of Murray street) by the Board of Trustees of the College. That the change which the introduction of the metric system in England and America would involve would cost some slight temporary inconvenience is not for a moment doubted; but as this inconvenience would be felt for a few weeks only, and as the subsequent benefit will be almost incalculable, it is felt that too much cannot be done to make the simplicity of the system intelligible to all classes, and to expose the fallacy of the objections which have from time to time been urged against it. The nature of the inconvenience to be overcome may be compared to that experienced upon his first visit to France by an Englishman, who has always been accustomed to shillings and pence—he forgets that the franc is not divided duodecimally, and, therefore, if he spent 7 décimes he expects 5 décimes as change of a franc. The difficulty, however, is overcome in a few days.

The origin and nature of the metric system of weights and measures, which Dr. Barnard details in a preliminary chapter, is particularly interesting. It was one of the projects entertained by the Constituent Assembly of France at the time when the Revolution had not yet passed into that sanguinary phase which but too soon succeeded, to engage the nations of Europe in a united effort to create for the common use of all a new metrological system founded upon standards determined with scientific accuracy, and constructed in its details according to a scientific method. The subsequent turmoil prevented unity of action amongst the nations; yet the metric system of weights and measures was devised—a system so nearly perfect that after a lapse of only three quarters of a century it has been adopted for use by more than half the inhabitants of the civilized world. In the International Commission, invited to Paris by the Government, were represented the Governments of France, Holland, Denmark, Sweden, Switzerland, Spain, Savoy, and the Roman Cisalpine and Ligurian republics, and the standard metre bar of platinum, which represents the linear base of the system, and the standard kilogramme weight, also of platinum, which represents the linear base of the system, were deposited in the Palace of the Archives on the 4th Messidor An VII. (June 22, 1799), and have since served as the standards with which to compare those for other countries which have adopted the system.

From information obtained at the Universal Exposition of 1867, Dr. Barnard is enabled to give some interesting particulars as to the progress of the great movement toward metrological uniformity. First in the order of time after France, Holland, and Belgium, came the kingdom of Greece, which adopted the metric system of weights and measures as early as 1836; but a little before this (1833) the Zollverein had been formed, and the zollpfund of 500 grammes, or half a kilogramme, adopted as the common unit. This came into use on January 1, 1840, and was found so convenient that in several States—Prussia, Wurtemberg, etc.—it was subsequently adopted as the national as well as the international pound. In Italy the metric system was brought fully into force in Sardinia from January 1, 1850; it was established in the Pontifical States soon after; and by a law passed July 28, 1861, was extended over the entire Italian peninsula, and also over Sicily from January 1, 1863. Shortly after the revolutionary excitement of 1848, Austria entered the Zollverein, and the metrical weights and measures were introduced into that kingdom. Switzerland has enjoyed the advantage of a metric system since 1856. In 1852, Denmark grammes decimally divided. In 1855, Sweden partially adopted

a decimal system, which was improved in 1865, and extended to Norway in the following year. In Spain and her colonies the metric system was established in 1859, and Portugal adopted it in 1864, in which year Roumania also passed a law prescribing the use of the system from January 1, 1865. Even Turkey has recently made a beginning towards bringing her system into harmony with that which is now so rapidly becoming the system of all continental Europe. In 1864 the system was legalized in Great Britain, but it was thought preferable to allow some delay before rendering its use compulsory.

That the ultimate triumph of the system is inevitable is admitted by all who have given the subject any consideration, and it may be hoped that the rebuke which Dr. Barnard administers to Americans will not prove equally applicable to Englishmen—that we must look to a generation who is not so mentally one-sided as ours; a generation in whose training the good shall not be placed at so tremendous a disadvantage as it has been in our own; a generation which shall bring to this great metrological question a judgment at once fair, candid, unbiased, and unwarped by the prejudices which mislead and bewilder us,—to produce the impartial decision for which it must be sadly admitted we seem disqualified ourselves. In dealing with the several objections which have been urged against the metric system by those who have not studied it, Dr. Barnard gives those objections the full weight to which they are entitled, but he shows that the advantages to be derived far more than compensate for the inconvenience to be encountered in making the change; and he points out that in former times far greater, although less useful, changes have been made without leading to serious inconvenience. He shows, moreover, that the tendency in every nation has been towards the unification of the weights and measures of our people under the same Government; and a stronger argument in favor of general unification could scarcely be desired. In fact, every alleged difficulty has been fairly and ably met by Dr. Barnard, and no doubt it will be hereafter acknowledged that his exertions have done much to hasten that wished-for reform which will aid in the realization of Mr. Adams's prediction that the metre will surround the world in use as well as in multiplied extension, and one language of weights and measures will be spoken from the equator to the poles.



## REPORTS OF ENGINEERS' SOCIETIES.

THE SCIENTIFIC AND MECHANICAL SOCIETY, MANCHESTER.—At the fifth monthly meeting of the session of the above Society, held at the Trevelyan Hotel, Mr. Hacking read his paper "On the Ventilation of Mines." He said there were now about 30,000 coal mines in the United Kingdom, from which the enormous quantity of 120,000,000 tons of coal were raised annually. The depths at which these black treasures—constituting such an all-important ingredient in the wealth of this country—were stored varied very much, the deepest workings in this country being the Dukinfield and the Rosebridge collieries, near Wigan, which latter had a depth of 2,418 ft., and the average temperature was about 95 deg. Fah. The danger attending the getting of coal was very great; this was partly due to the peculiar position in which the miner was placed, and partly to the terrible agencies reigning at these depths. A great difficulty was to obtain an efficient supply of pure air, for which mechanical means had almost invariably to be adopted. A very common mode of ventilation was by means of 1, 2, or 3 shafts; at or near the bottom of one—the upcast—a fire was kept which rarefied the air above, in consequence of which new air rushed in from the downcast, which had to make its way through the workings, and lastly to the fire. The life of those employed in the pits was much endangered by what was called "firedamp," which was light carburetted hydrogen ($C_2$ $H_4$) mixed in certain proportions with oxygen, or, what was the same, atmospheric air. The gas itself, which issued from the pores and crevices of the coal, was inexplosive; but if atmospheric air contained more than 7½ per cent. and less than 15 per cent., the results were most terrible if that mixture came in contact with a naked flame, when it would explode. The supply of pure air was, therefore, required to be very ample, in order to keep the mixture below the explosive point. As a rise in the barometer indicated a decrease in the pressure of the atmosphere, a larger quantity of the gas would always be liberated when such a rise took place, and he suggested registering barometers, which might be made to actuate an alarm as a safeguard. Mr. Hacking was just alluding to the use of fans for ventilation when the time arrived at which it was arranged that the subject should drop and continued at a meeting in the ensuing session. Mr. Lynde then introduced the discussion on Sir William Fairbairn's new patent high-pressure boiler, which he illustrated by a good photograph and sketches on the black-board, confining his remarks, however, to structural arrangements only. The boiler, which is intended to carry much higher pressure (about 150 lbs. on the sq. in.) than has hitherto been attained in the Lancashire and Cornish boiler, is already tolerably well known to scientific readers. It is essentially what is technically known as "French boiler," "Woolf boiler," "Elephant boiler," or "Bouilleur boiler," with this material difference, however, that each of the two bottom tubes have internal flues containing the fire-grates, the same as a Lancashire boiler.

These flues, which form an annular waterspace through the whole length, are so arranged that for the purpose of cleaning by loosening a few bolts they may be withdrawn from the tubes, which latter are about 3 ft. in diameter, communicating with one another. The entire circular shell constitutes heating surface. Hosts of questions were asked with regard to constructive detail, relative value of evaporating surface, etc.; but the object of the discussion being merely to ventilate the opinion and probable experience of the members, only few questions could be satisfied, no paper having been prepared for the purpose. Various advantages and drawbacks were pointed out, but no defined decision was come to.—*Engineer.*

AMERICAN INSTITUTE OF MINING ENGINEERS.—The American Institute of Mining Engineers held their second tri-annual session in the hall of the Western University of Pittsburgh, on the 16th and 17th of October, on which occasion James Park, Jr., welcomed the members of the Institute, and addressed them upon the importance of their calling and mission, in a neat and pertinent address, which was responded to by the President of the Institute, in the course of which he urged the necessity of scientific mining, in view of the rapid development of our industries, calling for additional supplies of fuel alluded to and the dearth of mineral coals abroad. The subjects announced for discussion were "The Iron Trade," "Coal Washing and Coke Making," "Coal Fields and Ores of Colorado," "The Presence of Phosphorus in Anthracite Coal," "Coal Analysis," and "The Tennessee Iron Works." E. C. Pechin, President of the Dunbar Furnace Company, read an interesting paper on "The Iron Trade." On Thursday the President read a paper on "The Tertiary Coal Beds of Canyon City, Colorado," by Prof. R. N. Clarke, who was not present. Papers were read and addresses delivered by the following gentlemen, on the subjects following their names respectively:

Prof. J. Blodgett Britton, of the "Iron Masters' Laboratary," in answer to the question, "Do the Pennsylvania Anthracites contain Phosphorus?" The Professor demonstrated that they do. The following subjects were also brought forward: "The Capacity of Measurement by Weight of American and English Blast Furnaces," "On a New Occurrence of the Telluride of Gold," "The Pressure of Gas in Coke Furnaces," "On Coal Washing and Coke Furnaces." Prof. Cox delivered an address on the "Analysis of Coals."

It will be be seen that the proceedings were of an interesting character, and that the mining engineers are alive to the importance of their calling. —*Coal and Iron Record.*

THE Council of the Institution of Civil Engineers have awarded the following premiums and prizes for work done during the session of 1871-2: A Telford medal and a Telford premium in books to each of the following gentlemen: Bradford Leslie, for his "Account of the Bridge over the Gorai River, on the Goalundo Extension of the Eastern Bengal Railway;" Carl Siemens, for paper on "Pneumatic Despatch Tubes: the Circuit System;" W. Bell, for paper on "The Stresses of Rigid Arches, Continuous Beams, and Curved Structures;" J. H. Latham, for description of "The Soonkesala Canal of the Madras Irrigation and Canal Company;" G. Gordon, for paper on "The Value of Water and its Storage and Distribution in Southern India;" A Telford premium in books to F. A. Abel, F. R. S., for paper on "Explosive Agents Applied to Industrial Purposes;" and the same to Bashley Britten, for paper on "The Construction of Heavy Artillery, with reference to Economy of the Mechanical Forces Engaged." The Manby premium in books to C. Andrews, for paper on the "Somerset Dock at Malta." A Miller prize each to Oswald Brown, for paper on "Sewage Utilization;" A. T. Atchison, for paper on "Railway Bridges of Great Span;" J. Addy, for paper on the "Most Suitable Materials for, and the Best Mode of Formation of, the Surfaces of the Streets of Large Towns;" A. E. Preston, for paper on "Wood-Working Machinery;" W. P. Orchard, for paper on "The Education of a Civil Engineer."

SOCIETY OF ENGINEERS.—The first meeting of the Society for the session of 1872-3, was held on Monday evening last, the chair being occupied by the President, Mr. Jabez Church. A paper was read by Mr. E. G. Bartholomew, on "Telegraphic Batteries." The author commenced by referring to the two papers he had previously read before the Society on the subjects of telegraphic conductors and telegraphic instruments, observing that the present paper on batteries would render the subject complete. He compared the electric telegraph to the steam engine; the conductor represented the steam pipe, the instrument the engine, and the battery the boiler. The author then went on to describe the different kinds of batteries, the principles of their construction, and to explain the laws by which the force generated was governed. Pointing out that the force generated was proportionate to the chemical action and to the consumption of some of the elements of the battery, he showed the necessity for preventing any such action or decomposition from proceeding unless the resulting force was utilized. The author further showed how by rendering the surface of the most oxidizable metal homogeneous, local action was suppressed. The various methods of joining up the elements, whether as forming one large plate or in series, was alluded to, and the resulting character of the force explained.

THE AMERICAN SOCIETY OF CIVIL ENGINEERS. The eighth annual meeting of this Society was held on the 20th anniversary of its foundation, November 6th last, at the Society rooms, 63 William street, New York.

Papers as follows were presented:

"Record of some experiments showing the character and position of Neutral Axes as seen by Polarized Light," by Louis Nickerson, C. E., of St. Louis, Mo. "Coal Cutting Machinery in England," by T. Guilford Smith, C. E., of Lansingburgh, N. Y.; and "Alcohol as an Illuminator in the Condensed Atmosphere of New York Caisson, East River Bridge," by Francis Collingwood, C.E.

The annual report of the Board of Direction upon the affairs of the Society, with brief memoirs of two of the members who died during the year, was read.

From this report it appears:

During the past year the attendance at the

meetings of the Society was greater than during any former year, while the interest manifested, the number and value of contributions to the "Transactions," the discussions thereon, the liberal and progressive spirit shown in reference to suggestions from time to time made, and the decided increase in membership, exhibit in a gratifying manner the regard among American engineers for the welfare of the Society.

The additions to the Society during the year were:—

Members—elected 83—qualified 71—resigned 3—dead 2.

Making increase 66.

Associates:—elected 5—qualified 3—resigned 1—become member 1, making increase 1—67; fellows 13—a total increase in members of 80.

The present membership is:

Members:—resident 103—non-resident 175—total, 278.

Associates:—resident 2—non-resident 4—total, 6—making 284—fellows 61—making total numbers 345.

During the year 22 meetings, exclusive of the Annual Convention, were held, 6 of which, in the winter, were in the evening. At these meetings, and the Annual Convention 30 papers on a diverse range of professional topics were read. At times the reading was followed by profitable discussion upon these topics and others of kindred interest.

Twenty papers and the proceedings of the Annual Convention were published during the year; and most of these were reprinted in the leading engineering journals.

By donation and purchase there were added to the library of the Society in the same time nearly 1,200 books and pamphlets, including 53 volumes of "Specifications and Drawings of Patents," current series, 55 photographs and maps, and 10 models.

It is hoped that soon the Society may devote a fixed portion of its revenue to the regular increase of its library by the purchase of rare important scientific and technical works.

Mr. George H. Newman, of Newport, R. I., has contributed a fund sufficient to provide yearly a suitable medal, to be awarded for the best essay of practical engineering interest, either description of structures complete or in course of erection, or a record of experiments illustrating well-defined theory.

The Treasurer's report shows the finances of the Society to be in a satisfactory condition, and, by the recent increase of membership fees and dues, abundant pecuniary means for all its purposes are assured.

The first annual convention of the Society was held in Chicago, June 5th and 6th last. The largest number of American civil engineers ever brought together were present, who contributed to make the occasion one of rare professional improvement and sound enjoyment.

Two valued members died during the year—Major S. S. Post, one of the founders of the Society, and Col. M. D. Davidson, who early became a member.

A report was presented on a plan for the organization of local branches or chapters of the Society, which was referred to the Membership for discussion by correspondence with the Secretary, to be taken up for final action at the next annual convention.

The next and Fifth Annual Convention of the Society will be held at Louisville, Ky., May 14th and 15th next.

During the winter, beginning with November 20th, the meetings on the third Wednesday in the month will be held in the evening, and devoted exclusively to the discussion of professional subjects, while the meetings on the first Wednesday of the month will be held in the afternoon, when the routine business of the Society will also be taken up.

Officers were elected for the ensuing year as follows:

Horatio Allen, President; Julius W. Adams, Jacob M. Clark, Vice-Presidents; Gabriel Leverich, Secretary; James O. Morse, Treasurer; Alfred W. Craven, Thomas F. Rowland, John Bogart, George S. Greene, Francis Collingwood, Directors.

Subsequently the Standing Committees were appointed.:

On Finance, Messrs. Craven, Rowland, and Bogart.

On Library, Messrs. Morse, Leverich, and Clark.

## IRON AND STEEL NOTES.

THE PIG IRON TRADE*.—The iron trade of America seems on the point of a new departure. After years of struggling against heavy odds, patient endurance in periods of depression and loss, fears and hopes alternating as failure or success seemed to be the penalty or reward, wanting in sufficient capital, embarrassed by reason of imperfect knowledge and lack of skilled labor, confronted by a powerful foe—every doubt has at last vanished, physical and mechanical difficulties have been largely overcome, capital has become more abundant and remunerative, the excellence of our product has been everywhere established, and the peculiarities of American character—pluck, energy and perseverance—have at last placed the trade upon a foundation so broad and stable, that upon it we begin to erect the structure of a world-wide business.

Concerning the future of the iron trade in the United States there can be but little doubt. The growing scarcity and constantly increasing cost of raw material in Great Britain, their loss of labor by emigration, the social disturbances among the working classes, assuming a more threatening attitude on each new outbreak, the rapidly decreasing value of money, in consequence of the enormous production of gold and silver, combine to forbid any return to former prices, and indicate that a point has been reached beyond which any marked increase is improbable. The same causes are operating to a greater or less extent upon the Continent. In the meanwhile the growing wants of humanity are rapidly outstripping these resources of supply. In addition to the steadily increasing foreign home demand, we find, the world over, the most intense activity everywhere displayed in enterprises requiring prodigious quan-

*Extract from a paper, read before the meeting of the American Institute of Mining Engineers, by Mr. E. C. Pechin.

tities of iron. Railways of colossal magnitude are building or projected in Russia, Australia, the East Indies, North and South America, and now the hoary and laggard East unbars its venerable portals and invites, with open arms, the fresher and nobler civilization of the West to renew its life by giving to it what the other, out of its own fertile brain, has created.

In the United States, irrespective of the 60,000 miles of road to be maintained, and the 5,000 miles annually building, the uses of iron are almost infinite. Day by day the application of iron and steel in new directions, and in novel forms is increasing. It is authoritatively stated that at the present rate of annual consumption, in eight years the forests of Maine will have disappeared. In the Northwest the ravages of fire and the axe of the woodman are rapidly diminishing that source of supply.

This growing scarcity of timber is *compelling* the use of iron in buildings, bridges of wonderful size and strength, huge ocean steamships, barges and boats for lake and river traffic, churches, cars, and thousands of minor articles of every shape and size. Thus looking over the whole field of operations, the present is most favorable—the future most promising. Thus far what has been said applies equally to all branches of the iron and steel business.

*The Future of Pig Iron.* What follows is applicable more particularly to the manufacture of pig iron. That the stocks of raw irons are inconsiderable the world over seems to be admitted. The chances are against any material increase abroad, so that the only matter likely to disturb the home market is excessive domestic competition. From the very nature of the business, it can only be increased with moderate rapidity. Under the most favorable circumstances it takes a long time to build a modern furnace—the capital required is very great, allowing only men of large means to engage in such an enterprise. The localities naturally adapted for the business are comparatively few. A still greater obstacle in the time and money needed to open mines and deliver materials. Whether the furnaces in existence to-day can obtain full supplies of ore for the ensuing year is by no means a settled question, and from all the data obtainable to date, the probabilities are against it. The outlook, therefore, is favorable.

But all this may change—excessive prices may check consumption, and a falling off of demand may cause lower prices, and possible loss; unexpected crises may come, just as they have come before; causeless panics may again unsettle trade. It is, therefore, a duty that each man owes to himself to ward off a disaster by present watchfulness. The American ironmaster should plan, construct and manage, as if the barest profit that rewards capital and labor were his; as if he were assailed on all sides by the fiercest competition at home; as if he had to seek the market of the world for his living, and find himself opposed to the products of all nations and countries.

To build up a business that will be permanently successful, that will grow with our nation's growth and strengthen with her strength, we must put ourselves in a position to make as good an article, and sell it as cheaply, as any other people can or will, and anything short of this is practical failure.

IRON VS. STEEL RAILS.—The startling assertion is made by "The American Railway Times" that "on the Boston and Albany Railway some 12,000 tons of iron rails were laid last year, and of this amount 800 tons have been removed from the track as useless or unsafe." In consequence of such shortcomings in point of service, the managers of several roads upon which a large business is conducted have concluded to import steel rails from Europe, the "Times" relating an instance of one lot of 9,000 tons. In the earlier days of rail-making in England, great care was exercised in producing a very superior quality of iron, which, made into rails, would do service for a period of twenty years, while our "good iron" of the present day will be rendered unfit for duty in about eight years. At this rate, it would be a matter of economy on the part of railway companies to pay just double the present rates for rails that would last twenty years. And when we count the cost of relaying, it would be found cheaper to pay even more than twice the cost of the rotten rails named by our contemporary.

It is stated in this connection by the "Times," that a pair of 21 ft. Bessemer steel rails upon the London and Northwestern Railway outlasted sixteen faces of iron rails, being evenly worn to a depth of a little over a quarter of an inch, having in about three years sustained the traffic of upward of 9,000,000 engines and cars, or about 95,000,000 tons. These two rails were at last destroyed by an accident. It was estimated that they would have endured at least one and a half as much more tonnage had they continued in use. From the above statements, we can gather some idea of the vital importance of securing for railway service iron of the best quality, not only in view of its economy, but in consideration of the safety insured to passengers by its employment in railway construction.—*Coal and Iron Record.*

EXPERIMENT ON THE STRUCTURE OF IRON.—In some recent experiments made in France, interesting information has been made known in regard to crystalline structure in wrought iron. The apparatus consisted in a bent axle, which was firmly fixed up to the elbow in timber, and which was subjected to torsion or twist, by means of a cog-wheel connected at the end of the horizontal part. At each turn the angle of torsion was 24 deg., and a shock was produced each time that the bar left one tooth to be raised by the next. Seven axles were submitted to the trial. In the first the movement lasted one hour, 10,800 revolutions and 32,400 shocks being produced; the axle, $2\frac{6}{10}$ in. diameter, was taken from the machine and broken by an hydraulic press, but no change in its texture occurred. In the second, a new axle having been tried 4 hours, sustained 129,000 torsions, and was afterwards broken by means of an hydraulic press; no alteration was perceptible to the naked eye, but, tried by a microscope, the fibres appeared without adhesion, like a bundle of needles. A third axle was subjected during 12 hours to 338,000 torsions and broken in two; a change in its texture and an increased size in the grain of the iron were observed by the naked eye. In the fourth, also, the axle was broken in many places after 110 hours and 2,553,000 torsions. In the fifth, an axle submitted to 23,328,000 torsions during 720 hours, was completely changed in its texture. In the sixth,

after 10 months, during which the axle was submitted to 78,735,000 torsions and shocks, fracture produced by an hydraulic press showed clearly an absolute transformation, the surface of the rupture being scaly, like pewter. The seventh axle, submitted to 129,304,900 torsions, presented a surface of rupture like that of the sixth, the crystals were found to be perfectly well defined, the iron having lost every appearance of wrought iron.—*U. S. R. R. and Mining Register*.

THE FRENCH IRON TRADE.—Numerous orders are being received by French ironmasters on foreign account. The production of Bessemer steel is being carried on in France on a considerable scale and upon favorable conditions; the Orleans and Rouen Railway Company is about to establish a Bessemer converter at works recently purchased.

## RAILWAY NOTES.

RAILROADS IN RUSSIA.—The new railway in Russia are progressing much less rapidly than was anticipated at the opening of the year. The Yaroslavi-Vologda and Lozovo-Sebastopol lines are still far from complete, and the Poti-Tiflis, which was to have been opened in the winter of 1870–71, is not yet fit for use. Less is now heard about the great "strategic" lines concerning which so much was said; at present, the railways projected from time to time are almost exclusively commercial, intended either to connect isolated factories with the general railway system, or to perfect the communication between ports (especially those of the Baltic seaboard) and the interior. The Bourse "Gazette" announces the projection of a new line of this kind, from Vazma to Rjeff (meeting the Rjeff-Torjok Railway, which is now in process of construction) in order to open up the flax-growing districts and connect them with Moscow.

VIENNA TRAMWAYS.—There are eight lines of tramways in Vienna, nearly 22 kilometres (13½ miles) in extent, or a length of single line of 44 kilometres (26 miles). The average number of horses employed in 1870 was 1000, and the Tramways Company possess nearly 400 cars, of three different kinds. About one-fourth are winter cars, with two closed compartments (one for smokers), and 18 seats. The summer cars are open, with a roof covering supported on standards; they are 7 metres long and contain 21 seats. There are also composite cars for the two seasons, of the same length as the summer cars, but with open ends, and a closed central compartment. The gauge is 1.9 metres, or nearly 6 ft. 3 in., and the minimum radius of curvature is 8 metres, or nearly 9 yards. The total number of passengers conveyed during the year was 12,548,000, and their average fare was 2½d.

IMPROVEMENTS IN STREET CARS.—Mr. John Stephenson, the well known street car and omnibus builder of new York city, whose passenger vehicles may be seen in nearly every country on the globe, has recently received patents for various improvements in their construction, which consist as follows: The first invention relates to securing the metallic connection between the running gear and the body of the car, which is accomplished by interposing rubber or other elastic material between the parts, so as to reduce the discomfort experienced by passengers from the noise of the wheels, the clattering of the parts, and the jar occasioned by applying the brakes. The next improvement consists in making the axle-journal without a shoulder, and placing a spring check at the end, by which arrangement, as the car is forced from side to side through inequalities in the track, the concussions are relieved by means of the spring check. The third invention provides means for securely holding and fastening the caps of car-axle journal-boxes, and the fourth improves the construction of car-brakes, so as to simplify the same and facilitate repairs.—*American Railway Times*.

LIMA AND OROYA.—A synopsis of the report of the Company shows the following details: From Lima to Oroya is 120 miles; highest altitude to be reached, 16,000 ft.; greatest grade, 4½ to 5 per cent.; gauge, 4 ft. 8 in.; ultimate destination, head of navigation on the Amazon, more than 100 miles east of Oroya; first-clas engines required by contract to stock the road, 2); time given to complete it, 6 years; terms of contract, $27,000,000. The distance and altitude are given in round numbers; the distance may be a few miles more or less, but the altitude is certainly not less, and probably may be more.

Trains run up to Rio Seco, 50 or 60 miles beyond E. Up to this point the work has been light in comparison with the next 30 miles beyond, which will embrace most of the deep cuts, bridges, tunnels, etc., as well as the highest altitude. For the first 25 miles, to Chosica, the grade is very light, the railroad keeping up the Rimac river and close by its side for many miles. At this point will be located one of the repair shops of the railroad. Passing Chosica, the grade rapidly increases, and the valley contracts until it is finally pinched entirely out, and the railway winds up a narrow defile. Twenty-five miles beyond is San Bartholomew, a cluster of 20 or 30 native huts. Here will be another small repair shop and engine house. Four miles beyond is Rio Seco, the present terminus of the road. A little above this men are at work blasting the solid rock for the first tunnel. Rio Seco is more than a mile above the sea. Two trains a day from Lima arrive at Rio Seco, and all material for stations beyond is forwarded upon mules. On the return the trains use no steam, the grades being so uniformly down that a light hand-car started at Rio Seco will run to Lima by its own gravity. Six first-class locomotives are now in operation, and others are on the way around the Horn. They are all made expressly for heavy draught engines. The grade is so steep that seven loaded cars is the largest train that has ever yet been taken to Rio Seco. The greatest credit is due the engineer (Mr. Harry Meiggs) for the manner in which he has surmounted very great obstacles and difficulties. The work goes steadily on, and the Peruvian Government demonstrates its increasing confidence in the engineering abilities of Mr. Meiggs by awarding him contract after contract over all competitors, and the liberal policy he has manifested toward all those in his employ, has elevated the American character in the eyes of the Peruvian people far above that attained through any diplomatic influence.—*Railway Review*.

INCLINED PLANES—THE CENTRE RAIL SYSTEM.—The centre rail system, first proposed and practically tested 22 years ago, on the Panama Railroad, is about to have another trial; this time to be made in Brazil, on the Cantagallo Railroad, which bids fair to occupy an important place among the engineering works which have done so much to develop the resources of Brazil. At present the important coffee-producing district of Cantagallo, situated at a high level (separated from the lowlands by the Organ mountains), has to transport its produce by mules across the mountains to Caxoeira, from which a railroad of 5 ft. 3 in. gauge has for 13 years past extended to Rio Janeiro. This costly and uncertain transportation by mules led to a desire to extend the railway communication across the Organ range into the heart of the Cantagallo district, and ultimately there was obtained a franchise to build a railroad from Caxoeira across the mountains to Nova Friburgo, to be ultimately extended 60 miles further to Cantagallo. This line, now constructing, has a gauge identical with that of the Mont Cenis Railroad, and that part of it traversing the coast side of the mountains will be laid with the centre rail. In 7¾ miles this mountain portion rises about 3,000 ft., the gradient varying from 1 in 20 to 1 in 12, and for the greater part 1 in 13, while the curves are about 140 ft. radius. The permanent way of the mountain portion of the line is identical in construction with that of the Mt. Cenis Railroad. The rails weigh 65 lbs. per yard, the central one being raised 9 in. above the ordinary carrying rails, and bolted to wrought-iron chairs, which are secured to a longitudinal sleeper fixed to the ordinary transverse sleepers. As in the case of the Mt. Cenis Railroad, also, the mid-rail will only be laid on the steep inclines, the ends of each length being tapered so that the gripping wheels may pass on and off easily. Recent trials of locomotives seem to have proved satisfactory. The engine is carried on two pairs of coupled wheels of 2 ft. 4 in. diameter, driven by cylinders 13 in. in diameter with a stroke of 14 in., while a second pair of cylinders, 14 in. in diameter and 12 in. stroke, drive two pairs of horizontal *gripping wheels* 1 ft. 10 in. in diameter. The wheel base of the engine is 7 ft., while the two pairs of horizontal gripping wheels are placed as close together as possible, and are situated midway between the axles of the vertical wheels. The pair of cylinders driving the horizontal wheels are arranged on the centre line of the engine, one above the other, the piston rod of each cylinder being attached to a long transverse crosshead suitably guided, from the ends of which connecting rods lead off to cranks on the axes of the leading horizontal wheels. The axis of each horizontal wheel has two cranks at right angles to each other, the two axes on each side of the centre rails being connected by coupling rods, while the leading axis of each pair so coupled is driven by the connecting rods already mentioned. The axes of the horizontal wheels are mounted in bearings carried by cast-steel cradles, so arranged that by means of a right and left-handed screw, the gripping wheels can be made to exert a pressure of any desired amount up to 40 tons on the mid-rail. The engines for driving the horizontal and vertical wheels are independent of each other, with two regulators and two sets of reversing gear, and an independent ordinary and mid-rail brakes. With these arrangements the tractive power is estimated as enormous—with a clean rail the adhesion is reckoned at six tons, at the least; and the experiments thus far made seem to demonstrate the practicability of these locomotives, and hence the efficiency of this most difficult line of railway.—*Railway Review.*

THOMAS A. SCOTT, Esq., Vice President of the Pennsylvania Railroad Company, gives the following testimonial in regard to the Wharton switch:

"After careful experiment upon our road at several points where it could be most thoroughly tested, during which you have perfected the Wharton Railroad Switch, so that we think it adapted to all our wants, we have concluded to adopt it on our own road and the roads leased by us; and will give it place as rapidly as we can do so consistently with the proper maintenance and operation of the line.

"I believe that it will prove of great practical value to all the railways of the country."

## ENGINEERING STRUCTURES.

THE MONSTER DERRICK.—Some months since, the Delamater Iron Works constructed, for the Department of Docks, a 100-ton floating derrick, which is now in successful operation, and is the most powerful structure of its kind in the world. It was constructed for the purpose of transporting and laying under water the huge monoly ths of artificial stone or béton which form the lower part of the river wall which is to surround the water front of the city, and has a lifting power of upwards of 100 tons.

The float which carries the derrick is of rectangular form, 66 by 71 ft., and 13 ft. in depth. It is built for the most part of Georgia pine, put together in the strongest manner, in order that it may stand, without twisting, the heavy loads it carries on its deck, as well as the strain caused by the great weights which are lifted by its boom. The float is stiffened by 16 trusses, extending from the deck to the bottom, and running across from side to side.

The tower, which is placed upon the float, and which carries the derrick proper—viz.: the king post and booms—is made of 12 baulks of Georgia pine, 63 ft. 3 in. in length, and 14 in. square; these balks or legs are stiffened from one end to the other by struts and braces; their lower ends are bolted into a heavy cast-iron circle, which, in its turn, is held down by numerous bolts, which pass down through the bottom of the float. At their upper extremity these legs are brought close together and are inserted in a heavy cast-iron cap, to which they are bolted. The tower thus described accordingly forms a frustrum of a cone 40 ft. in diameter at the base, 62 ft. in height, and 12 ft. in diameter at the top. The cast-iron cap which surmounts it is made with a circular hole, through which the king post passes.

The front or hoisting boom of the derrick consists of two wrought-iron box girders 22 in. deep by 9½ in. wide; these girders are made with the greatest care, the plates having been accurately planed and all the rivet holes drilled, instead of punched.

These girders are spaced 24 in. asunder, and are held securely parallel by appropriate braces of wrought iron; on the upper and inner edges of these girders a track or slide of polished brass is fastened by countersunk screws; these tracks have a projector which extends a short distance downward; the carriage which carries the main hoisting blocks slides on these tracks. The carriage is composed of two plates of iron ¾ in. in thickness, and spaced 10 in. asunder; its length is 8 ft., its depth 3 ft. When its under side bears upon the track, a sliding surface is formed by two pieces of ash wood, well saturated with grease, and extending the entire length of the carriage; similar pieces are attached along the sides. This arrangement works exceedingly well, the carriage, with its heavy load, moving with perfect steadiness. At each end of the carriage are placed cast-iron sheaves; around these sheaves the wire rope passes which runs the carriage in and out on the boom. Heavy wrought-iron bands are fastened to the carriage, which extend downward to the under side of the boom, and to them are attached the main hoisting blocks; the upper one of these two blocks is so secured that it will hang perpendicularly, no matter how much the float may careen under a heavy weight or unequal loading. The front or hoisting boom already described is supported by 18 diagonal rods 2⅛ in. in diameter, of iron, which resist 75,000 lbs. per square inch tensile strain; these rods converge near the top of the king post, and are secured to it by three heavy forgings, which straddle the iron cap on the top of the post. These forgings extend backward sufficiently to receive the counter stays, which are 3¾ in. in diameter, and which extend to the end of the back boom. The back boom is similar to the front one, except that it is composed of one box girder.

The king post is wrought iron, 40 in. outside diameter. It is hollow, and its shell is ¾ in. thick. The king post is supported as follows: Its lower end is 12 ft. below the top of the tower, through which it passes, and it is inserted in a circular casting; this casting bears upon another casting some 12 ft. in diameter, and reaches radially to the tubular legs of the tower to which it is secured. The king post revolves in the lower casting, thus swinging the boom completely around.

The back boom, already mentioned, is held down by eight parts of 1⅜ steel wire rope, the breaking strain of each part being 78 tons. The rope is in one piece, and it is rove through sheaves on the end of the boom, and also through similar sheaves attached to the carriage on the traversing circle, already described, and which spreads over some 18 ft. of the circle. By this arrangement the heavy strain in distributed on the 8 parts of the rope. Under a strain of some 300,000 lbs. these guys do not yield enough to allow the side of this post to touch the front side of the casting on the top of the tower through which it passes.

The derrick has the power of giving three motions to its load: 1. The lifting motion; the gear for this purpose consists of two blocks with ten 24-in. sheaves in each; a wire rope 1¼ in. in diameter is rove through these blocks, the two ends passing down through the centre of the king post to a cast-iron drum 60 in. in diameter, which is driven by a pair of engines with 12 by 14 in. cylinders, connected by appropriate gearing; the bight of this hoisting rope passes around a horizontal sheave placed at the end of the boom, hence the carriage may be run in and out by changing the position of the load vertically. 2. The movement of the load in and out on the boom, the general arrangement of the carriage has been described, so that it is only necessary to state that four parts of wire rope are rove through each end of the carriage, the ends of the rope are carried down through the king post and wound in opposite directions around a drum driven by a pair of engines similar to those already described. 3. The movement of winging the load; this is done by wire ropes attached to the carriages, which roll on the traversing circle; these ropes pass in opposite directions around the circle and are wound in opposite directions around a drum similar to the one already mentioned. Although, as has been shown, there is a flexible connection between the traversing carriages and the end of the back boom, the boom follows the slightest change in the position of the carriages, and is instantly stopped by checking them.

The front and back booms form a continuous arm, being braced together laterally by a lattice truss of lozenge form, made of wrought iron.

All the machinery is placed on a float under the tower, and the levers which operate it, and which give the various movements mentioned, are brought together on a platform 35 ft. above the deck of the float, so that the person operating them acts in full view of the load that is being handled.

To repeat in part, the following are the chief dimensions of the derrick: Length of float, 77 ft.; breadth of float, 66 ft.; depth of float, 13 ft.; length of hoisting boom, 63 ft. 3 in.; length of back boom, 50 ft. 3.; length from end to end of booms, 110 ft. 6 in.; height from bottom of float to top of king post 127 ft. 3 in.

This general type of derrick was projected by Bishop many years ago; but those that have heretofore been built are of very inferior construction to this one. The one above described is a thorough engineering structure from top to bottom. It has many mechanical refinements, to which is due the marked success which has attended its working under very heavy loads. The novel arrangement of the wire guys on the back boom, spreading, as they do, the strain over a large section of the traversing circle, may be particularly mentioned.—*Nautical Gazette.*

THE ST. GOTHARD TUNNEL will have a length of 9.2 miles, and will be entirely on a straight line. The summit rail load in the middle of the tunnel will be 3,788 ft. above sea level. The same section of tunnel as on the Mont Cenis is to be adopted, 26 ft. 2 in. wide, and 19 ft. 8½ in. high. From geological indications the following strata will have to be pierced, and in the order named: Granitic gneiss, 2,050 yards; gneiss, 393; schists (with marble), 3,050; granitic gneiss, 4,100; gneiss, 508; granitic gneiss, 2,500; gneiss and mica schist, 1,545; hornblend and schist, 1,336; dolomite and gypsum, 710; making a total of 16,192 yards. Contractors are invited to submit proposals with reference to the work up to the 18th of next May, to the administration of the St. Gothard Railway.

## ORDNANCE AND NAVAL.

AMERICAN STEAMSHIPS.—We have left to us one line of American ocean steamships of which we have a right to feel proud—the line which connects San Francisco with China and Japan. It seems that the China steamers of the Pacific Mail Company are to follow the fate of other American ocean steamers. A new fleet of magnificent English ships is to be put on the same route. These vessels may not surpass in speed, comfort, or safety, the American steamers, but the former are propelled by the screw, while the latter still adhere to the paddle-wheel.

THE GREAT RUSSIAN IRON-CLAD.—A St. Petersburg correspondent of the "Daily News" describes the launch of the sea-going turret ship Peter the Great from the Admiralty dock-yard there. The vessel received its name from the Grand Duke Constantine, in the presence of a great concourse of people. The wedges were withdrawn simultaneously, and the great ship glided without check or noise into the Neva. The vessel has been designed by Admiral Popoff, an officer of the highest distinction, who is well and favorably known in England. His ship differs in many respects from the American and English turret ships. While as good a piece of mechanical construction as any of Mr. Reed's vessels, she is in size, height, form, buoyancy, stability, and engine power, able to make a long voyage of 17 days at a high speed in any condition of weather. The Peter the Great is 329 ft. 8 in. in length between perpendiculars. Her greatest outside breadth in 63 ft. The builder's measurement is 5,352 tons, and the displacement, with coals, stores, and water in boilers, will be 9,665 tons, at a mean draft of 23 ft. 9 in. The plates on the ship's sides and raised building amidships vary from 12 to 14 in., and the armor-plate protects the ship to a depth of 6 ft. below the water line. The vessel has no spur, but the upright stem is heavily plated, and of enormous strength. The ship has two large turrets, which are plated with 16 in of iron, in two thicknesses of 14 and 2 in. She has no masts, but depends entirely on her engines, which have been built by the Widow Baird. The engines are on the compound principle, and in construction resemble the Messrs. Rennie's latest type. Each engine is 700 horse power, and connected with two four-bladed screws. There are 12 boilers, which will require at full speed 132 tons of coal in 24 hours, at which rate of consumption the engines will work at 10,000 horse power effective, and the ship will be driven at 14½ knots speed per hour. If the engines are worked at second grade of expansion she will have coal for 17 days, steaming 12½ to 13 knots per hour. With the single exception of the teak-wood backing, all the materials of the ship, engines, and armament have been produced in Russia, by Russian workmen. The iron plates of which the hull has been built were made of Russian iron, at the Imperial factories of Petrozavodsk and Kolpino. These plates are of superb quality charcoal iron, much superior to the best Yorkshire plates in respect of closeness of fibre and toughness. The armor plates, also of Russian iron, were all rolled at Kolpino, 25 miles from St. Petersburg, and are of the finest description. They will, it is said, sustain the blows of the heaviest shots without splitting. The four cannon for the Peter the Great are being made at the Imperial foundry of Alexandrofsky, nine miles from St. Petersburg. Each gun is of steel, built up like Vavasseur's gun, and breech-loading on a system which differs but little from Krupp's. The bore is 12 in., and the projectile of 700 pounds will be propelled at a velocity exceding 1,400 ft. per second. The steel from which the guns are made is oil tempered, and of very fine quality, superior in respect of strength and toughness to either Krupp's or the Woolwich Arsenal tube metal.—*Nautical Gazette.*

THE NAVAL FORCE OF FRANCE.—From statistics recently published, it appears that the French fleet now consists of 104 war vessels afloat, of which seven are armor-plated, and 73 on trial or in reserve, including 17 armor-plated, making a total of 181. The navy comprises 27,993 men. Next year the fleet will consist of 94 vessels afloat, 8 iron-clad, and 62 in reserve or on trial, or allotted for training, 19 of them being iron-clad. The naval service will have an effective force of 28,431 men. A sum of 22,000,000 francs will be set apart during the two years for new building, and ought to provide 12 new vessels. When the number of ships condemned by the committee of investigation is taken into account, this figure does not seem sufficiently high; but, on the other hand, it must be remembered that the power of increase will be greatly extended by the plan in future to be adopted, of building in private yards, of which there are many more now than in former days.

## BOOK NOTICES.

INTRODUCTION TO CHEMICAL PHYSICS. By THOMAS RUGGLES PYNCHON, M. A. New edition, revised and enlarged. New York: D. Van Nostrand.

A new branch of scientific instruction has been added within the last few years to those generally considered indispensable to a course of scientific study. It appeared first in the technical schools, but is now finding a place in the academies and preparatory schools. The work before us is the latest, and, so far as we have examined similar treatises, the best contribution to this department of human knowledge. It is quite as much a supplement to the course of so-called Natural Philosophy as an introduction to Chemical Physics; and still "all matters" says the author, "of which a knowledge could equally well be obtained from any good treatise on Natural Philosophy, have been omitted."

The leading topics in point of interest—those which the reader would experience difficulty in finding so fully elucidated in the standard text-books, we briefly set forth below.

After a short chapter, devoted chiefly to the different states of matter and the nature of chemical forces, the topic of Heat is discussed in the fullest manner. Under the title "Diffusion of Heat," conduction, connection and radiation are of course explained, and in the usual order, but with a degree of fulness not to be found in other so-called text-books. Sixty pages are devoted to this section alone. In the treatment of Radiation, the latest discoveries regarding diathermancy are fully

set forth. Some of the topics are as follows: Diathermancy not proportioned to transparency; Melloni's experiments on diathermancy of solids; the diathermancy of liquids; the diathermancy of gases, unequal diathermancy of heat from the same source, owing to a property of bodies called Thermochrosis.

The Second Section treats of Expansion due to Heat; the useful effects of such expansion receiving special attention. The various forms of thermometers and pyrometers are illustrated largely by wood-cuts interspersed in the text.

Liquefaction forms the subject of the Third Section under the general topic of "Effects of Heat." The Heat of Composition, Heat of Fluidity, and the Theory of Fluxes are the leading items among numerous important and interesting ones.

Section Four deals with Ebullition, and Section Five with Evaporation. Seventy-five pages are not considered too much space in which to elucidate these important phenomena and their relations to practical science. Of course engines and boilers receive a fair share of attention; but so also do such topics (unusual in books designed for class instruction) as "fractional distillation," and "the relative economy of employing other vapors than that of water in our engines."

Specific Heat, The Sources of Heat, and The Nature of Heat are treated respectively in the Sixth, Seventh and Eighth sections. Many valuable tables are included in this portion of the book, all of which are of the highest importance to the worker in either the physical or chemical laboratory.

Under the head of Light, in Chapter Third, we find a very complete, yet concise account of the spectroscope, its uses, and the late discoveries effected by it. Many spectra are exhibited by wood-cuts.

Electricity, Static and Dynamic, Magnetism, Electro-Magnetism, Magnets, Electricity, and Thermo-Electricity form the subjects of the Fourth and last chapter of the book. Batteries of many forms, their theories and adaptability respectively to various uses, are described in the most thoroughly practical manner. Telegraphs, Electro-Motors, and Electric Clocks follow next in order. The Economy of Magnetic Engines Compared with Heat Engines is discussed in a brief section that might be committed to memory with lasting profit by many young aspiring inventors at the present day

The theories of magnetic and electric induction are stated with clearness and precision. Ritchie's and Ruhmkorff's coils, together with their applications, are described at length. The earliest and latest forms of magneto-electric machines are discussed in their order, and include such applications as Wilde's and Ladd's machines for illuminating purposes.

The Correlation and Conservation of Physical Forces appropriately ends the book.

It will be inferred from the above analysis that while nothing relating to *atomic* forces is treated in the work, as this is the province of chemistry proper, nothing is left to be desired in the treatment of *molecular* motions and forces. The author's plan comprehends a course of elementary chemistry to follow this introduction.

Most readers of scientific treatises, whether students or not, would find in this book much that is valuable, especially in the aid its tables and descriptions would afford in understanding the more technical and scientific discussions which are so frequent in our scientific journals. As a book of reference for such use, we know of no single work which could so well answer the purpose.

The instructor will find the suggestions for illustrative experiments of especial value.

LECTURES ON MINERALOGY delivered at the School of Mines, Columbia College, by Prof. T. EGLESTON. New York: D. Van Nostrand.

This work is a treatise on descriptive mineralogy, in which "only those species are described with which it is necessary for an engineer of mines to be familiar, or which present some peculiarity of interest."

The lectures were prepared for the students of the School of Mines, and have been printed with special reference to facilitating their labor. So much the author explains in the preface. Students of a practical turn of mind elsewhere in the country, who have not enjoyed the benefit of the lectures will not be slow to draw the conclusion that a work designed to aid students in the first mining school in the land, will be of the highest value to those who wish to study this science with reference to such applications.

The descriptions of the physical characteristics of minerals, together with their behavior under the blow-pipe is exceedingly lucid.

The crystalline forms are given at the end of the book in thirty-four full-page plates.

TABLES FOR FACILITATING THE COMPUTATION OF THE QUANTITY OF WATER FLOWING OVER WEIRS. Supplement to FRANCIS' HYDRAULIC EXPERIMENTS.

There are two tables only, occupying seven quarto pages. The first gives Heads in full due to velocities from 0 to 4.99 ft. per second.

Table Second shows "the discharge in cubic feet per second of a weir 1 ft. long, without contraction at the ends, for depths from 0 to 2.99 ft.

A COMPENDIOUS MANUAL OF QUALITATIVE CHEMICAL ANALYSIS. By CHAS W. ELIOT and FRANK H. STORER. Revised with the cooperation of the authors, by Wm. Ripley Nichols. New York: D. Van Nostrand.

The original edition of this work having been exhausted, while the demand for it was still increasing, a new supply was an obvious necessity. In the meantime, its use in the laboratory of the Massachusetts Institute of Technology had suggested to the revising editor some alterations and additions, which accordingly appear in the present issue.

To the beginner in analysis, this work presents many advantages not easily found in other works designed for the same class of students. Among these may be mentioned the very copious appendix, detailing in an admirably clear manner the proper method of conducting laboratory work. This description is aided by many illustrations.

The whole work is divided into two parts. Part I. is divided into chapters, each single chapter from the second to the eighth being devoted to a *class* of metals. The ninth and tenth discuss the properties of non-metallic elements.

Part II. deals with preliminary examinations

and general methods of procedure. Many instructors will doubtless prefer to present these *Parts* to their students in the inverse order; but this can be done at the pleasure of the teacher, and without involving explanations not contained in the book.

## MISCELLANEOUS.

A NEW COLONY IN THE WEST.—The Kansas Pacific Railroad Company recently sold to Sir George Grant, London, Eng., about 24 square miles of land, in Ellis county, Kansas, lying on Big Creek and Smokey Hill River. The location, as respects fertility of soil, a good climate and easy accessibility, is highly favorable, and a credit to the discernment and good judgment of the purchaser. It is the intention of this gentleman to found a colony of English and Scotch farmers and mechanics, and to import with them a lot of fine blooded stock of horses, sheep, and horned cattle. A fine stone quarry underlies a portion of the purchase, from which materials will be taken for a handsome depot and for public edifices, etc. The colonists will probably make a specialty of grazing and "blooded" stock-raising, since every facility will be afforded to do so. Sir George is not only wealthy but influential among his countrymen, and, what is better, enthusiastic in his specialty or pet project of introducing good farmers to good farms. With such means and disposition there is no doubt that the tract he has bought can and will be made a perfect garden. All this cannot, of course, be done at once, but as successive ship loads of emigrants flock in, and as the circle enlarges by this and the natural increase of population, and so too in the extent and value of their work on a virgin soil, in a district so accessible to markets for every salable product, the future of this enterprise can reasonably be pronounced successful. The colony, or rather the township which it will make up, is to be appropriately called Victoria, as we are informed.—*Railway Review.*

BALLARAT MINES.—I have said that among Victoria gold fields, Ballarat is famous for alluvial dirt to be washed—not for quartz to be crushed, as is the case with Sandhurst. But the reader must not therefore suppose that Ballarat is a place of mere surface scratching—an agglomeration of gullies from which the earth is shovelled into cradles—a congregation of "fossickers," who search about, picking and washing a bit of earth here and a bit there. The alluvial dirt which produces the greater portion of the wealth of Ballarat has not only to be brought up many hundred feet from under the surface, but it has to be sought for through underground passages thousands of feet in length, and has to be followed up by geological deductions which too often fail in their promise. I went down one such mine, called Winter's Freehold, descending 450 ft. in an iron cage. I was then taken 4,000 ft. along a tramway in a truck drawn by a horse. At the end of that I was called upon to mount a perpendicular ladder about 20 ft. high, and was then led along another tramway running apparently at right angles to the first. From this opened out the cross passages in which the miners were at work. Here we saw the loose alluvial grit—so loose that a penknife would remove it—lying on the solid rock to the breadth of about 4 ft. Here and there among the grit, with candle held up and some experienced miner guiding my eye, I could see the minute specks of gold in search of which these vast subterranean tunnels had been made. It seemed to be but a speck here and there—so inconsiderable as to be altogether unworthy of such labor. I was told that £150,000 had been expended on this single mine, and that the machinery was the finest in the colony. I heard also that the results hitherto had not been magnificent. But it was thought that a good time was coming, and that all the money expended would certainly come back with copious interest. We were two hours seeing the mine, and I cannot say that, as regarded immediate enjoyment, the time was well spent. The place was wet and dirty and dark, and the effect to the eye very poor. But such is the result to all amateur inspectors of mines. When we had extricated ourselves from the bowels of the earth we ascended to a platform on the top of the machinery, to which the wash-dirt is brought up that it may be "puddled" and the gold extracted. The height enables the water and mud to run off. The dirt is placed in a round flat receptacle or trough, into which water is pumped up, and an instrument something like a harrow is worked through it. The water and mud are amalgamated, and they escape: the gold by its own weight falls to the bottom, together with stones and shingles. This is then sent down to an open spout below, though which water again runs, a man the while working it with a fork prepared for the purpose. Again the stones and mud pass off with the water, and again the gold remains behind, sinking to the bottom by its own weight. When all has escaped that will escape, and the stones which will not fall have been thrown out, then the specks of gold are seen lying thick, collected in the little furrows which are marked in the bottom of the spout. To the uninitiated eye the product of all this labor still seems to be small. The precious metal is then smelted and sold to the banks. At present the greater portion of the gold found at Ballarat is worth over £4 an ounce. I must add, that they who are sanguine as to Ballarat predict a vast wealth of qartz reefs for the locality after the wash-dirt has been all extracted.—*Daily Telegraph.*

PROPOSED HARBOR WORKS AT CAITHNESS.—We have received, and have much pleasure in giving publication to, a communication in relation to the provision of a good harbor on a part of our coasts that is by no means too well provided with such accommodation of a suitable character. It is not because this is the Ultima Thule of "John o'Groat's," that the subject should therefore be esteemed as of small account, from an imperial point of view. The nation that allowed itself to be beguiled into the undertaking of Alderney Harbor, may well look somewhat favorably upon a really useful and practicable scheme at the other extremity of the United Kingdom. The recent visit of the Chancellor of the Exchequer to Wick savors of some inchoate inception of "justice to Scotland;" and now that he is a freeman of that amphibious borough, there will be "no peace for the wicked," if he does not in some sort realize their fond expectations.

# SCIENTIFIC BOOKS.

'RANCIS' (J. B.) Hydraulic Experiments. Lowell Hydraulic Experiments—being a Selection from Experiments on Hydraulic Motors, on the Flow of Water over Weirs, and in Open Canals of Uniform Rectangular Section, made at Lowell, Mass. By J. B. FRANCIS, Civil Engineer. Second edition, revised and enlarged, including many New Experiments on Gauging Water in Open Canals, and on the Flow through Submerged Orifices and Diverging Tubes. With 23 copperplates, beautifully engraved, and about 100 new pages of text. 1 vol., 4to. Cloth. $15.

Most of the practical rules given in the books on hydraulics have been determined from experiments made in other countries, with insufficient apparatus, and on such a minute scale, that in applying them to the large operations arising in practice in this country, the engineer cannot but doubt their reliable applicability. The parties controlling the great water-power furnished by the Merrimack River at Lowell, Massachusetts, felt this so keenly, that they have deemed it necessary, at great expense, to determine anew some of the most important rules for gauging the flow of large streams of water, and for this purpose have caused to be made, with great care, several series of experiments on a large scale, a selection from which are minutely detailed in this volume.

The work is divided into two parts—PART I., on hydraulic motors, includes ninety-two experiments on an improved Fourneyron Turbine Water-Wheel, of about two hundred horse-power, with rules and tables for the construction of similar motors:—Thirteen experiments on a model of a centre-vent water-wheel of the most simple design, and thirty-nine experiments on a centre vent water-wheel of about two hundred and thirty horse-power.

PART II. includes seventy-four experiments made for the purpose of determining the form of the formula for computing the flow of water over weirs; nine experiments on the effect of back water on the flow over weirs; eighty-eight experiments made for the purpose of determining the formula for computing the flow over weirs of regular or standard forms, with several tables of comparisons of the new formula with the results obtained by former experimenters; five experiments on the flow over a dam in which the crest was of the same form as that built by the Essex Company across the Merrimack River at Lawrence, Massachusetts; twenty-one experiments on the effect of observing the depths of water on a weir at different distances from the weir; an extensive series of experiments made for the purpose of determining rules for gauging streams of water in open canals, with tables for facilitating the same; and one hundred and one experiments on the discharge of water through submerged orifices and diverging tubes, the whole being fully illustrated by twenty-three double plates engraved on copper.

In 1855 the proprietors of the Locks and Canals on Merrimack River, at whose expense most of the experiments were made, being willing that the public should share the benefits of the scientific operations promoted by them, consented to the publication of the first edition of this work, which contained a selection of the most important hydraulic experiments made at Lowell up to that time. In this second edition the principal hydraulic experiments made there, subsequent to 1855, have been added, including the important series above mentioned, for determining rules for the gauging the flow of water in open canals, and the interesting series on the flow through a submerged Venturi's tube, in which a larger flow was obtained than any we find recorded.

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